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FOSSIL FORAMINIFERA FROM THE BURDWOOD BANK AND THEIR GEOLOGICAL SIGNIFICANCE

By

W. A. MACFADYEN, M.C., M.A., Ph.D., F.G.S.
Sedgwick Museum, Cambridge

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FOSSIL FORAMINIFERA FROM THE BURDWOOD BANK AND THEIR GEOLOGICAL SIGNIFICANCE

By W. A. Macfadyen, M.C., M.A., Ph.D., F.G.S.
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(Text-figs. 1, 2.)

Fossil Foraminifera were recognized in bottom deposits from several stations of the R.R.S. 'Discovery II' and the R.R.S. 'William Scoresby'[1], and in the present investigation samples dredged from three stations on the northern part of the Burdwood Bank were examined.

DESCRIPTION OF SAMPLES

1. A dredging at St. WS 87 in lat. 54° 7½′ S, long. 58° 16′ W, dated 3. iv. 1927, came from a depth of 96 m. It yielded a bottom sample comprising sand, with recent shells and Foraminifera, etc., together with many fragments of shale, and loose fossil Foraminifera.

The shale all consisted of rounded pebbles, the largest of which measured 7 × 6 × 3 cm. The larger pebbles were partly stained by a brown surface coloration and were pierced by borings, up to 6 mm. in diameter, of present-day marine organisms; several recent specimens of Polyzoa and Foraminifera were adherent to their surface. The shale was of two kinds, both being rather hard, but showing no sign of crushing or thermal metamorphism. Most was of a green-grey colour, highly glauconitic (best seen at the eroded surface where the glauconite grains were left prominently exposed), and very finely sandy. Traces of the original bedding were visible in some of the pebbles. The less common type consisted of slightly sandy micaceous shale, light grey when dried, and of exceedingly fine texture, without glauconite. There was a single pebble, 2·5 cm. long, of rather soft grey argillaceous limestone.

The loose Foraminifera examined numbered about 110 and were in many cases badly crushed and distorted, while some were preserved as calcite casts. *Haplophragmoides subglobosus* and species of *Cyclammina* were the commonest forms. Mr Earland found a number of the specimens specifically and some generically indeterminable, a conclusion I fully share. Thirteen, all of arenaceous species, had traces of green finely sandy shale adhering to them.

The two kinds of shale were washed separately for Foraminifera. Nearly all of those obtained came from the fine light grey shale, with *Spiroplectammina spectabilis* and

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[1] See Heron-Allen, E., and Earland, A., 1932, Foraminifera. Part I, The Ice-free Area of the Falkland Islands and Adjacent Seas, *Discovery Reports*, IV, pp. 297–8, Cambridge.

Globigerina bulloides as the most frequent forms. The glauconitic shale was practically barren. The specimens, sixty-eight of which were mounted, were in general not crushed, and many were filled with clear calcite. Of the following list, therefore, which is largely Mr Earland's work, many species are quite well preserved, whilst others are yet nameable, though sometimes doubtfully.

Fossil Foraminifera identified

	St. WS 87		St. 719		St. 720		Geological range		
	L	S	L	S	L	S	Cretaceous	Tertiary	Living
Bathysiphon sp.	...	...	14	...	...	...	...	...	...
Ammodiscus incertus (d'Orbigny), A and B forms	4	1	21	...	...	1	×	×	×
Glomospira charoides (Jones and Parker)	4	...	...	1	...	...	×	×	×
G. gordialis (Jones and Parker)	1	...	...	...	...	...	×	×	×
Hormosina globulifera, Brady	2	...	...	...	...	...	×	×	×
Haplophragmoides acutidorsatus (Hantken)?	2	...	...	...	...	...	×	×	...
H. aff. *crassimargo* (Norman)	1	...	...	...	...	...	...	...	×
H. subglobosus (Sars)	28	...	...	1	...	...	×	×	×
H. coronatus (Brady)	3	...	...	...	...	...	×	×	×
Trochammina squamata, Jones and Parker	1	...	...	...	...	...	...	×	×
T. globigeriniformis (Parker and Jones)	1	...	...	1	...	...	×	×	×
Cyclammina cancellata, Brady	10	...	16	...	1	...	...	×	×
C. orbicularis, Brady	12	...	4	...	...	...	...	×	×
C. bradyi, Cushman	1	...	6	...	...	...	...	...	×
C. elegans, Cushman, A and B forms	...	...	36	...	...	...	×	...	...
Rzehakina epigona (Rzehak)	1	...	...	...	...	...	×	?	...
Spiroplectammina spectabilis (Grzybowski), A and ? B forms	1	14	...	1	...	4	×	...	...
Pseudotextularia globulosa (Ehrenberg)	1	...	...	...	...	...	×	?	...
Bolivina punctata, d'Orbigny	...	1	...	...	...	...	...	×	×
Bulimina pupoides, d'Orbigny	1	...	...	...	...	...	...	×	×
B. ovata, d'Orbigny	2	...	...	...	...	...	×	×	×
Allomorphina cretacea, Reuss?	1	...	...	...	...	...	×	...	...
Nodosaria ambigua, Neugeboren	1	...	...	...	...	...	...	×	×
N. limbata, d'Orbigny	1	...	...	...	...	...	×	...	...
N. communis (d'Orbigny)?	...	4	...	...	...	...	×	×	×
Cristellaria rotulata (Lamarck)?	...	1	...	...	...	...	×	×	×
Globulina gibba, var. *globosa*, Münster	...	1	...	...	...	...	...	×	×
Ellipsopleurostomella sp.	1	...	...	...	...	...	...	...	...
Valvulineria allomorphinoides (Reuss)	...	1	...	...	...	...	×	...	...
Gyroidina nitida (Reuss)	...	3	...	...	...	...	×	...	...
Globigerina bulloides, d'Orbigny	...	18?	...	...	...	...	×	×	×
G. cretacea, d'Orbigny	4	...	...	...	...	...	×	×	×
Pullenia sphaeroides (d'Orbigny)	...	4	...	...	...	...	×	×	×
Anomalina ammonoides (Reuss)	...	1	...	...	...	...	×	×	×

L = found loose; S = washed from shale. The figures in the table indicate the number of specimens mounted.

The specimens are preserved in the Heron-Allen and Earland Collection in the British Museum (Natural History), slides No. TS 525 (1)–TS 525 (5).

In view of the records of Radiolaria from Cretaceous strata of this region, noted below, it is of interest and importance to record finding in the residue from the grey shale four specimens of a radiolarian species. In shape it suggests a slightly spinose form of the foraminifer *Orbulina*.

2. A dredging at St. 719 in lat. 54° 00′ S, long. 60° 00′ W, dated 13. xi. 1931, came from a depth of 108 m. It consisted of greenish grey sand with recent shell fragments, Foraminifera, etc.; many fragments of greenish argillaceous limestone up to 9 × 6 × 5 cm., and bored by organisms; some smaller fragments of green-grey shale, brownish when dry; and many well-rounded pebbles[1] up to 6 × 5 × 3 cm., and to which recent organisms were adherent.

The shale was separated and washed, but yielded very few fossil Foraminifera, and five specimens of Radiolaria. The loose sand, however, yielded many fossil Foraminifera, some 125 of which were mounted: the most frequent forms included species of *Cyclammina*, particularly *C. elegans*, up to 3·1 mm. in diameter, *Ammodiscus*, and *Bathysiphon* fragments.

3. A dredging at St. 720 in lat. 53° 58′ S, long. 61° 10½′ W, dated 13. xi. 1931, came from a depth of 140 m. It consisted of greenish grey sand with many recent shell fragments, amongst which those of brachiopods were common, echinoid spines, Foraminifera, etc.; a few small fragments of bored greenish argillaceous limestone up to 2·5 × 2 × 1 cm.; some greenish shale, in part very glauconitic; and a small quantity of well-rounded pebbles up to 2 × 2 × 1·5 cm.

The shale, separated and washed, yielded hardly any fossil Foraminifera. Four specimens of Radiolaria were picked out. The loose sand likewise yielded only a very few rather small fossil Foraminifera.

From the abundance of the smaller fragments of shale in all three samples, and of limestone, particularly at St. 719, it seems clear that the beds must outcrop on the sea-bottom at or close to the stations, and that no adventitious origin will explain the occurrence. The well-rounded igneous pebbles appear to have been washed out of a pebble bed, since such rounding of this material is not to be explained by movement on the sea-bottom, but is perhaps the result of beach conditions. No trace of macroscopic fossils was found in any of the three samples.

PREVIOUS RECORDS OF FOSSIL FORAMINIFERA FROM THE PATAGONIA-GRAHAM LAND REGION

Hyades, writing in 1887,[2] records (p. 124) numerous Foraminifera without further identification in sections of a "schiste argileux" from the coast of Cape Webley, Ponsonby Bay (between Tierra del Fuego and Cape Horn).[3] On p. 130 he records from Button Island, Ponsonby Bay, "schistes bleuâtres feuilletés, semblables à des schistes ardoisiers". He continues: "Mais ce qui rend cette roche intéressante, c'est l'abondance des squelettes quartzeux de foraminifères qu'elle renferme en très grande quantité. La structure intime de ces foraminifères a été effacée dans l'acte de la fossilisation. Cependant les contours sont assez nettement accusés pour qu'on puisse y reconnaître des formes anciennes (carbonifères ou permiennes) rappelant celles des *Textularia* ou des *Climacammina*. Nous ne pensons pas qu'une détermination paléontologique aussi incertaine permette d'arriver à des conclusions nettes relativement à l'âge de ces roches". This record has apparently often been referred to, as Richter notes, but without Hyades's final cautionary sentence. Its value for dating the strata is, however, negligible.

---

[1] See note on p. 16 below.

[2] 1887, *Miss. Sci. du Cap Horn*, 1882–3, IV, *Geologie*. Paris.

[3] See Fig. 2 below (p. 13).

M. Richter,[1] records (p. 535) from Staten Island and New Year Island a few Foraminifera from *Inoceramus*-beds of somewhat metamorphosed shales and limestones rich in Radiolaria. He figures "?*Oligostegina laevigata*, Kaufmann" and *Globigerina* sp. from Cape Conway, Staten Island. From the Argentine-Chile border in the middle of Tierra del Fuego he records (p. 537) a reddish grey dirty limestone rich in Foraminifera, whose chambers are mostly filled with light green glauconite. With them are a few Radiolaria and many macroscopic fossils. "?*Oligostegina laevigata*, Kaufmann" is figured from here. From the same locality he also records (p. 542) *Cristellaria rotulata* (Lmk.), and notes as seen in section *Cristellaria*, abundant *Globigerina*, and also *Textularia*, *Nodosaria* and "?*Oligostegina laevigata*, Kaufmann". Richter considers the age of these beds to be Albian on the ground of the occurrence in them of *Aucellina*. Specimens from Mount Tarn on the Brunswick Peninsula, Patagonia, consisted of a finely sandy grey limestone with pyrites, glauconite and mica (p. 537), and with Foraminifera, particularly "*Globigerina* cf. *cretacea*, d'Orb." which is figured. The chambers of the tests are filled, so he says, with amorphous silica. He concludes (p. 564) that in South Patagonia and Tierra del Fuego there have been found fossils possibly of Upper Jurassic age; certainly of Lower Cretaceous age; and of the Upper Cretaceous, Albian, and particularly Upper Senonian, the *Inoceramus steinmanni*-beds.

His *Globigerina* cf. *cretacea*, appears from the figures to be the true *G. cretacea*, but his *Oligostegina laevigata* is, as was Kaufmann's original form, too doubtful to identify.

R. Holland[2] had material from the islands east of Trinity Peninsula, Graham Land. From the Senonian of Seymour Island (or Snow Hill Island, there is doubt as to precise locality but not, apparently, as to age) he had four specimens, which he described and figured as two new species, *Ammodiscus grandis* (one specimen) and *Trochammina cretacea* (three specimens). The latter, however, appears to be a *Haplophragmoides*.

From the ? Pliocene *Pecten*-conglomerate of Cockburn Island Holland records and figures eleven species. Of the 304 specimens submitted to him five-sixths were *Cassidulina crassa*. The full list he identified as follows:

---

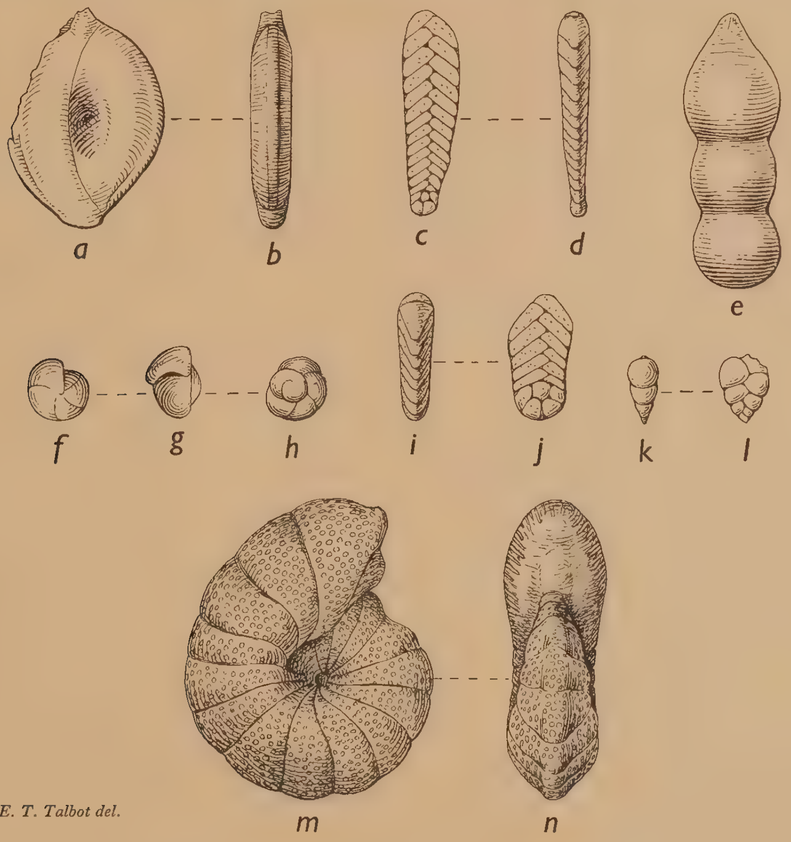
[1] 1925, Beiträge zur Kenntnis der Kreide in Feuerland, *Neues Jahrb. Min.*, LII, Beil-Bd., Abt. B, pp. 524–68, pls. vi–ix.

[2] 1910, The Fossil Foraminifera, pp. 1–11, pls. i, ii, *Wiss. Ergeb. Schwedisch. Südpolar-Exped.* 1901–3, III, Lieferung 9, 4to. Stockholm.

Biloculina ringens (Lamarck)
B. elongata, d'Orbigny
Miliolina grata (Terquem)
Cassidulina crassa, d'Orbigny
Lagena globosa (Montagu)
Cristellaria gibba, d'Orbigny
Polymorphina gutta, d'Orbigny
Truncatulina refulgens (Montfort)
T. lobatula (Walker)
T. ungeriana (d'Orbigny)
Rotalia beccarii (Linné)

AGE OF THE BURDWOOD BANK FAUNA

Of the fossil Foraminifera under discussion many have no value by themselves as age markers, since they range from the Cretaceous to the present day. Four species, however, *Rzehakina epigona*, *Spiroplectammina spectabilis*, *Pseudotextularia globulosa* and



E. T. Talbot del.

Fig. 1.

a, b. *Rzehakina epigona* (Rzehak), × 37; St. WS 87, loose.
c, d. *Spiroplectammina spectabilis* (Grzybowski), form ?B, × 37; St. WS 87, shale. The early part of the test is difficult to see clearly, and the initial chamber may have been over-emphasized in the figure. Alternatively the specimen may be the A_2 form.
e. *Nodosaria limbata*, d'Orbigny, × 37; St. WS 87, loose.
f, g, h. *Gyroidina nitida* (Reuss), × 37; St. WS 87, shale.
i, j. *Spiroplectammina spectabilis* (Grzybowski), form A, × 37; St. WS 87, shale.
k, l. *Pseudotextularia globulosa* (Ehrenberg), × 37; St. 87, loose.
m, n. *Cyclammina elegans*, Cushman, form B, × 18; St. 719, loose.

The age of these specimens is probably Upper Cretaceous (Senonian).

Cyclammina elegans, stand out, according to the literature, as a definite indication of an uppermost Cretaceous age. In the case of *Rzehakina* and *Pseudotextularia* (or *Gümbelina*, which name I take as a synonym) the genus alone would appear adequate for this age determination. *Nodosaria limbata* and *Gyroidina nitida* are also typically Upper Cretaceous species, but it is not quite clear that they are confined to strata of this age.

Pseudotextularia globulosa (Ehrenberg) was described from the Upper Cretaceous of various countries.[1] It has been recorded from Tertiary, Quaternary and even present day material, but in such cases I believe that it has generally occurred as a derived Cretaceous fossil, a point which has frequently not been made clear. It is often very abundant in Upper Cretaceous strata, and Cushman has frequently stated that in the American occurrences so far known it has not been found above the top of the Cretaceous.[2]

Spiroplectammina spectabilis (Grzybowski) was described from the Upper Cretaceous of Krosna, Poland, under the generic name *Spiroplecta*.[3] It has page priority over the megalospheric form,[4] described separately under the name *Spiroplecta brevis*, Grzybowski,[5] which is thus a synonym. Later, a rather broader microspheric form of what appears to be the same species was described under the name *Spiroplecta clotho*, Grzybowski,[6] also from the Upper Cretaceous of Poland. I am indebted to Mr Earland, who had a translation made from the Polish text, for the information that Grzybowski states that all three of the above species are "siliceous with a smooth surface".

The Burdwood Bank specimens are entirely siliceous; the wall of the test is fairly smooth, but is clearly composed of fine sand grains set in a large excess of cement.

Galloway and Morrey describe and figure a form under the name *Spiroplectammina rosula* (Ehrenberg) from the Upper Cretaceous of Mexico,[7] which seems to be the same as the megalospheric form of the Burdwood Bank species. They state that "The wall is now entirely siliceous, the surface is rough and granular, and there is little doubt that the wall was originally arenaceous".

The species does not appear to be recorded from other than Upper Cretaceous strata.

Cushman and others have described and figured forms from the Upper Cretaceous of Mexico and Trinidad under the name *Spiroplectoides clotho* (Grzybowski), which agree closely in shape with the present specimens.[1] Cushman's genus *Spiroplectoides*, with genotype *Spiroplecta rosula*, Ehrenberg, 1854,[2] was erected, however, for forms whose wall is calcareous and finely perforate, and it is therefore doubtful whether these records really refer to Grzybowski's species.

---

[1] 1838, *Abh. k. Ak. Wiss. Berlin*, p. 135, pl. iv, fig. β, frequens.

[2] E.g. J. A. Cushman, 1926, *Contrib. Cushman Lab. Foram. Research*, II, p. 16; 1931, *op. cit.*, VII, p. 39; 1927, *Amer. J. Sci.*, XIII, p. 324. Since writing the above, a new species, *Gümbelina wilcoxensis*, has been described by Cushman and Ponton from the Wilcox formation, or upper part of the Lower Eocene, of Alabama, U.S.A. (1932, *Contrib. Cushman Lab. Foram. Research*, VIII, p. 66, pl. viii, figs. 16, 17).

[3] 1898, *Rozpr. Ak. Umiej. (Mat.-Przyrod.) Krakow*, ser. 2, XIII, p. 293, pl. xii, fig. 12.

[4] There seems a possibility that trimorphism may be shown by this species, in which case the A_1 form may be Grzybowski's *S. brevis*; A_2, *S. spectabilis*; and B, *S. clotho*.

[5] *Loc. cit.*, p. 293, pl. xii, fig. 13.

[6] 1901, *Rozpr. Ak. Umiej. (Mat.-Przyrod.) Krakow*, ser. 3, I, dz. B, p. 283, pl. vii, fig. 18.

[7] 1931, *Journ. Pal.*, v, p. 335, pl. xxxvii, fig. 10.

Rzehakina epigona (Rzehak) was described from a single specimen[3] from a deposit stated to be of "Alttertiär" age. Rzehak's appear to be the only records in the literature of the genus from alleged Tertiary strata. The species is recorded from the Velasco of Mexico[4] and a variety (var. *lata*) from the Upper Cretaceous of Trinidad.[5] What seems from the figure to be the same genus is described by Grzybowski[6] from the Upper Cretaceous of Galicia under the name *Spiroloculina inclusa*.

The paper in which Rzehak describes *R. epigona* gives no indication of the evidence on which he based the "Alttertiär" age of the strata in which it was found. The question is of importance, since other species, certainly one of which (*Pseudotextularia varians*) is now well known as an Upper Cretaceous indicator, were described from these beds. The question is earlier discussed at some length by Rzehak himself,[7] where he records, unfortunately without figures, and with many *nomina nuda*, 181 species and varieties of Foraminifera, from *a number of specimens of strata* collected by E. Kittl from the "Alttertiär" in the neighbourhood of Bruderndorf, Lower Austria. Rzehak concludes on balance that "the fauna" is of Tertiary age on the ground of a few poorly preserved orbitoids and a nummulite which he identifies with confidence as *Nummulites boucheri*, de la Harpe. He discusses the strong Cretaceous elements on pp. 7–9, and states that the fauna appears to be of the same age as the Leitzersdorf bei Stockerau Foraminifera, described by Karrer[8] definitely as Upper Cretaceous on the ground of the foraminiferal fauna. Rzehak admits that several of the Bruderndorf species are typical Upper Cretaceous forms, and that others differ very slightly from Upper Cretaceous species. Such are *Bolivina draco*, Marsson, *Cristellaria rotulata* var. *macrodisca*, Reuss, *Marginulina soluta*, Reuss, and forms closely allied to *Frondicularia reticulata* (Reuss), *F. interpunctata* (Reuss) (*sic*), *F. lanceolata*, Reuss, *F. angulosa*, d'Orbigny, *Vaginulina angustissima*, Reuss, *Cristellaria gosae*, Reuss, *C. bacillum*, Reuss, *C. nuda*, Reuss. To this list must be added *Pseudotextularia varians*, Rzehak (recorded in this paper under the name *Cuneolina elegans*), now well known only as an Upper Cretaceous fossil. To-day I think such species would be accepted as definitely dating the beds in which they occurred as

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[1] E.g. 1927, *Journ. Pal.*, I, p. 159, pl. xxviii, fig. 6; 1929, *op. cit.*, III, p. 32, pl. iv, fig. 5; 1932, *Proc. U.S. Nat. Mus.*, LXXX, Art. 14, p. 43, pl. xiii, figs. 5, 6.

[2] 1927, *Contrib. Cushman Lab. Foram. Research*, II, p. 77.

[3] From Zdaunek in Moravia, 1895, Ueber einige merkwürdige Foraminiferen aus dem österreichischen Tertiär, *Ann. k. k. Nat. Hofmus. Wien*, X, p. 214, pl. vi, fig. 1.

[4] 1927, Cushman, *Journ. Pal.*, I, p. 150, pl. xxiii, fig. 4; 1928, White, *Journ. Pal.*, II, p. 186, pl. xxvii, fig. 6.

[5] 1928, Cushman and Jarvis, *Contrib. Cushman Lab. Foram. Research*, IV, p. 93, pl. xiii, figs. 11 *a*, *b*; 1932, Cushman and Jarvis, *Proc. U.S. Nat. Mus.*, LXXX, Art. 14, p. 20, pl. vi, figs. 1 *a*, *b*.

[6] 1901, *Rozpr. Ak. Umiej. (Mat.-Przyrod.) Krakow*, ser. 3, I, dz. B, p. 260, pl. vii, fig. 20.

[7] 1891, *Ann. k. k. Nat. Hofmus. Wien*, VI, pp. 1–12.

[8] 1870, *Jahrb. k. k. Geol. Reichsanst.*, XX, pp. 157–84, pls. x, xi.

Upper Cretaceous. It seems probable that more than one fauna is represented in Rzehak's collection, the nummulite and orbitoids at least (noted by Karrer from near-by Eocene) having been accidentally introduced.

A paper by A. Liebus[1] describes a fauna largely similar to that recorded by Rzehak in his paper of 1891, but without the nummulite or orbitoids. As indicated in the title Liebus, following Rzehak, assigns it to the Eocene on grounds that do not appear to be adequate. He discusses the age on pp. 341–2, where he admits the very large and typically Upper Cretaceous element of the fauna, but relies on other species, of which he quotes three, to prove the Tertiary age. Of these three, *Glomospira gordialis* (Parker and Jones) has been recorded and figured from strata of most ages from the Carboniferous to the present day, including the Cretaceous. The other two species he records as *Vaginulina bruckenthali*, Neugeboren, and *Clavulina szaboi* (Hantken). The fauna (or faunas, for two are recorded) seems to be at least mainly of Upper Cretaceous age, and since Prof. Liebus did not collect the material himself it may perhaps not be quite free from suspicion of containing some admixed Tertiary forms.

An important paper by O. Kühn[2] gives the full fossil evidence for the presence of Danian strata, which are mapped as a number of small isolated outcrops in the Bruderndorf area. His map shows much more complex geological conditions than the older map indicated. A foraminiferal fauna of forty-one species is listed by Ozawa (pp. 550–2); while it contains some typical Cretaceous forms, species of *Pseudotextularia* are not included. The evidence of this paper increases the probability that part of Rzehak's mixed fauna is of Upper Cretaceous age.

It may be recalled that the Esna Shales of Egypt were once held to be of Eocene age, though they are now considered to be definitely Upper Senonian (Danian).[3] I have a considerable fauna of Foraminifera from them, hitherto unrecorded, including such forms as *Pseudotextularia varians*, Rzehak, and *P. globulosa* (Ehrenberg). The Esna Shales are thus probably equivalent to the Austrian strata noted above.

According to the literature, therefore, the forms *Pseudotextularia globulosa*, *Rzehakina epigona* (of which two, however, only a single specimen each was found in the Burdwood Bank material), and *Spiroplectammina spectabilis* may be taken as definitely indicating an uppermost Cretaceous age. This appears to be valid in both Europe and North and Central America. *Cyclammina elegans*, Cushman and Jarvis,[4] has recently been described from the Upper Cretaceous of Trinidad, and so strengthens the evidence for the presence of strata of this age on the Burdwood Bank. I have, however, lately examined three samples of material from the South American region, with results that cast doubts on the reliability of the first two species as Cretaceous indicators in that area. Unfortunately in two cases the history of the samples is not known sufficiently well to exclude any question of contamination, so that while there may be suspicion on the point proof is yet lacking.

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[1] 1927, Neue Beiträge zur Kenntnis der Eozänfauna des Krappfeldes im Kärnten, *Jahrb. Geol. Bundesanst., Wien*, LXXVII, pp. 333–92, pls. xii–xiv.

[2] 1930, Das Danien der äusseren Klippenzone bei Wien, *Geol. Pal. Abh., Wien*, XXI, Heft 5, pp. 492–576, pls. xxvi, xxvii.

[3] See W. F. Hume, 1911, *Quart. Journ. Geol. Soc.*, LXVII, pp. 124–8.

[4] 1932, *Proc. U.S. Nat. Mus.*, LXXX, Art. 14, p. 13, pl. iii, figs. 6 *a*, *b*.

Mr R. Wright Barker kindly allowed me to examine a sample of Foraminifera from the Clay Pebble Bed of Ancon, Ecuador, which is, so far as is known, of Eocene age, and no fossiliferous Cretaceous rocks are known or suspected, I believe, in the vicinity. In the sample I found a single specimen of *Rzehakina epigona*. The other Foraminifera did not suggest to me any definite age.

Some samples from the "Clay of Payta", North-west Peru, were sent by the late Dr José J. Bravo, Director del Cuerpo de Ingenieros de Minas at Lima, and are preserved in the Sedgwick Museum. They may have been collected from the Lobitos formation (Eocene), but in default of more than a locality label this cannot be stated as a fact. One tube contains an abundance of *Pseudotextularia globulosa* together with a number of other forms in the same state of preservation and of Tertiary aspect, such as *Nodosaria spinosa*, Berry, 1928, (*non* Neugeboren), described from the Eocene of Peru, *Dyocibicides* sp., *Ceratobulimina* sp., *Uvigerina* sp., and three forms of *Plectofrondicularia*, etc.

A third sample, from another locality, yielded many *Rzehakina* and abundant *Pseudotextularia globulosa*, together with some well-known forms described from the Eocene of the Mexican region, in the same state of preservation.

In addition to the four characteristic species noted above from the Burdwood Bank, the following may form part of the same probably Upper Cretaceous fauna; they have been recorded from the Upper Cretaceous particularly in the Mexican and West Indian region, and one, *Globigerina cretacea*, is often rather characteristic of it. Since the species, or such closely allied forms that it is not possible to separate them in the literature, nearly all occur in Tertiary deposits, and most are living at the present day, they are by themselves not of definite value as age markers:

Hormosina globulifera
Trochammina globigeriniformis
Haplophragmoides subglobosus
H. coronatus
Glomospira charoides
G. gordialis
Nodosaria limbata
N. communis
Cristellaria rotulata?
Allomorphina cretacea?
Valvulineria allomorphinoides
Gyroidina nitida
Globigerina cretacea
Pullenia sphaeroides
Anomalina ammonoides

The similarity of foraminiferal faunas in facies and species between localities so far apart as the Burdwood Bank and the Mexican-West Indian region (some 4000 miles direct), is remarkable; particularly when the great difference in latitude is considered, 54° S as compared with 10–25° N. But many species of Cretaceous Foraminifera are known to be of very wide range; they are identical in America and Europe according to Cushman,[1] and appear also to be the same in Australasia according to Chapman.[2]

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[1] Cf. 1931, *Journ. Pal.*, v, p. 298.

[2] Cf. 1926, *Pal. Bull.*, xi, *Geol. Surv. New Zealand*.

The similarity of the Burdwood Bank and Trinidad faunas is more readily understood when the rather deep-water facies of both is taken into account.

The widespread similarity of the Foraminifera is strikingly in keeping with the results obtained from a study of the Senonian ammonites of the South Patagonia-Graham Land region as noted below, while the Upper Senonian Mollusca are said to be similar to those of New Zealand.[1] The Tethys, according to Gregory,[2] had, in the Upper Cretaceous, perhaps its widest extension. It ranged during the Middle Senonian "from Kansas to England, Algeria, southern India, and to the Gingin Chalk of Western Australia. On the other side of the Pacific the European fauna reached northern Chile (23° S), doubtless through the West Indies...". Since the south Atlantic region appears to have been largely occupied by land at this period[3] the connection between the Senonian sea over the Mexican and South Patagonia-Graham Land regions must have lain to the west of the present South America.[4]

Of the Burdwood Bank fossil Foraminifera other conspicuous species are *Cyclammina cancellata*, *C. orbicularis* and *Ammodiscus incertus*. These three, with seven other species of the complete list above, have been recorded by Nuttall from the Tertiary (Upper Eocene to Middle Miocene) of Trinidad.[5] Nuttall's material is preserved in the Sedgwick Museum in Cambridge, and I have checked the agreement of his specimens with those from the Burdwood Bank. Certain of these species, particularly of *Cyclammina*, are common forms of the Trinidad tertiaries, and, taken into consideration with the regional stratigraphical development, may point to strata of similar age exposed on the Burdwood Bank. These arenaceous species can, however, be regarded only as evidence of similar facies, and not of age. Of a total of some 300 specimens of Foraminifera mounted there are at least eighty-six specimens referred to *Cyclammina* spp., so that it is a common genus, only approached in numbers in the collection by *Haplophragmoides* spp., of which there are at least thirty-five specimens, and *Ammodiscus* with twenty-seven. It may be noted, however, that these are all rather large forms found loose on the sea-bottom, and it is likely that they have been preserved owing to their size and stout build when smaller forms have been destroyed or removed.

The crushed state of many of the specimens, particularly of arenaceous species, is a feature which has been remarked by Cushman and Jarvis in the Trinidad Cretaceous (1928, *loc. cit.*, p. 85), and by Nuttall in the Trinidad Tertiary (1928, *loc. cit.*, p. 70). I have observed a severely crushed foraminiferal fauna from the Tertiary of Ecuador (Clay Pebble Bed of Ancon), and there are many badly crushed specimens in the fauna from the Clay of Payta, North-west Peru.

[1] Cf. J. W. Gregory, 1930, *Proc. Geol. Soc.*, p. xcviii.

[2] *Loc. cit.*, p. xciv.

[3] See Gregory, 1929, *Proc. Geol. Soc.*, p. cxviii, etc.; and von Ihring, 1931, *Quart. Journ. Geol. Soc.*, LXXXVII, p. 386, etc.

[4] See also A. Windhausen, 1932, *Zeitschr. Ges. Erdkunde, Berlin*, p. 28, text-fig. 2.

[5] 1928, *Quart. Journ. Geol. Soc.*, LXXXIV, pp. 57–115, pls. iii–viii.

CORRELATION OF THE REGIONAL STRATIGRAPHY

Marine Upper Cretaceous (Senonian) strata are known in Southern Patagonia and Tierra del Fuego,[1] where, following Wilckens, they are termed the San Jorge Series, and possibly extend up into the Danian. In Graham Land similar strata form part of the Snow Hill Beds and Seymour Island Beds.[2] In each area they contain an abundant fauna of ammonites; one that is common to both gives its name to beds in the Patagonian area, *Lahillia luisa*, Wilckens. This ammonite fauna is said to resemble those of the same age so far afield as Natal, Southern India, Japan and Vancouver. In addition the fauna includes corals, Mollusca, etc.

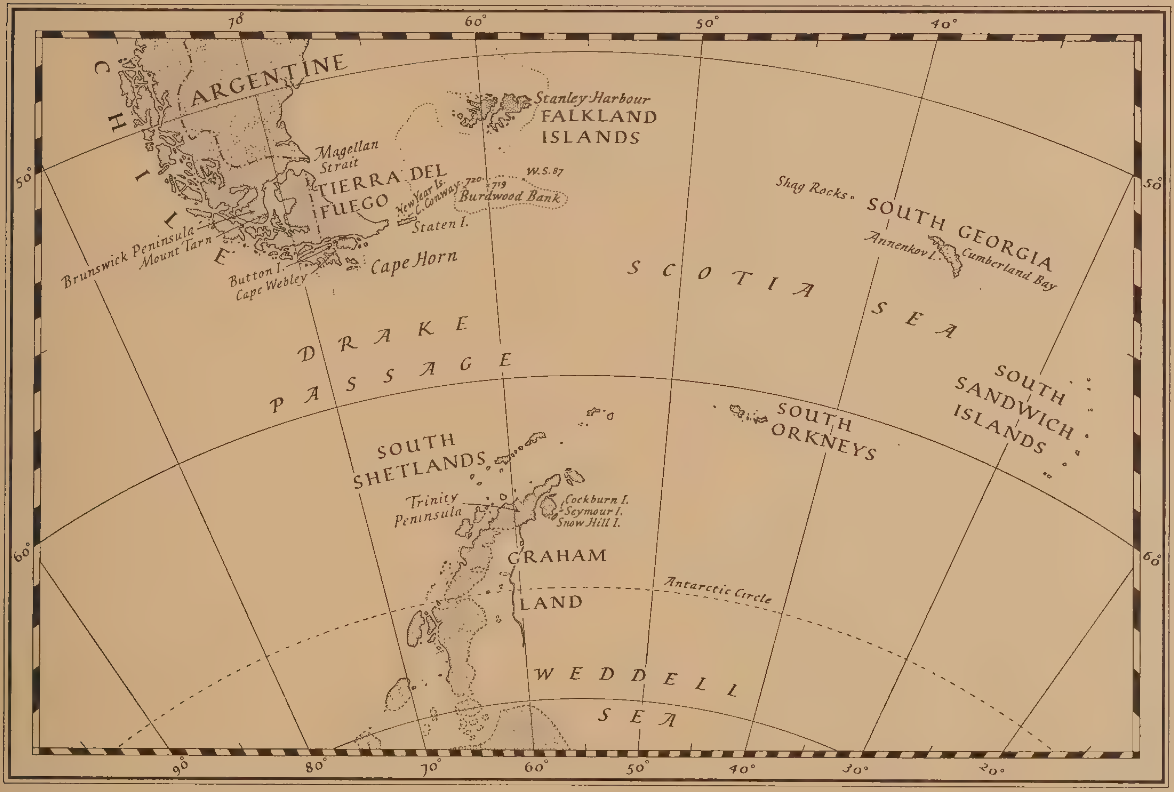
70°
60°
50°
40°
CHILE
ARGENTINE
Stanley Harbour
FALKLAND ISLANDS
Magellan Strait
TIERRA DEL FUEGO
New Year Is.
C. Conway
720
719
W.S. 87
Burdwood Bank
Staten I.
Brunswick Peninsula
Mount Tarn
Button I.
Cape Webley
Cape Horn
Shag Rocks
SOUTH GEORGIA
Annenkov I.
Cumberland Bay
SCOTIA SEA
DRAKE PASSAGE
SOUTH SHETLANDS
SOUTH ORKNEYS
SOUTH SANDWICH ISLANDS
Trinity Peninsula
Cockburn I.
Seymour I.
Snow Hill I.
GRAHAM LAND
Antarctic Circle
WEDDELL SEA
50°
60°
90°
80°
70°
60°
50°
40°
30°
20°

Fig. 2.

Through the kindness of Dr G. W. Tyrrell, material for comparison from the Cumberland Bay Series of South Georgia was available from the Ferguson Collection in the Hunterian Museum, University of Glasgow. From this series an ammonite was collected by Dr König of the German Antarctic Expedition under Lieut. Filchner, and is possibly of Cretaceous age; Radiolaria believed to be Mesozoic were found in the material in the Ferguson Collection.[3] The material now examined consisted of hard, altered and crushed sediments, which might well have compared, in their original state, with the Burdwood Bank shale. No Foraminifera were, according to Dr Tyrrell, observed in the sections in which the Radiolaria were found. Treatment of the material by disintegrating it in an iron mortar likewise unfortunately yielded me no trace of Foraminifera.

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[1] Cf. O. Wilckens, 1906, *Neues Jahrb. Min.*, Beil-Bd. XXI, pp. 98–195.

[2] Cf. T. G. Andersson, 1906, *Bull. Geol. Inst. Univ. Upsala*, VII (1904–5), pp. 19–71, 2 maps.

[3] In J. W. Gregory, 1914, *Geol. Mag.*, p. 64.

Tertiary strata are found following the Senonian in both Patagonia (cf. Wilckens, *loc. cit.*) and in Graham Land (cf. Andersson, *loc. cit.*). They often contain marine fossils and are said to extend in age from the Eocene to the Pliocene. In Patagonia they are known as the *Pyrotherium-Notostylops* Beds (Eocene and Oligocene, largely terrestrial but partly marine), Patagonian Molasse (Lower Miocene, marine), Santa Cruz Beds (Middle and Upper Miocene, largely terrestrial), and Paraná Beds (Pliocene, marine). In Graham Land the tertiaries appear conformably to follow the Upper Cretaceous in Seymour Island, and contain what is recorded as an Upper Oligocene or Lower Miocene assemblage of Mollusca; many of the forms are the same as those of the Patagonian Molasse. Von Ihring, however (*loc. cit.*, p. 387), states that the flora recorded from there by Oliver as Oligocene is really of Palaeocene age. The ? Pliocene *Pecten*-conglomerate is a much later deposit which rests unconformably on the older strata; Andersson (*loc. cit.*, p. 52) compares it with the Patagonian Paraná Beds.

The whole succession of Upper Cretaceous and Tertiary strata in the South Patagonia-Graham Land region may thus be compared, for instance, with that of Trinidad.

CONCLUSION

Hitherto the geological evidence from the Burdwood Bank appears to have been confined to the two soundings by Ross referred to by Suess,[1] which yielded volcanic rocks in lat. 54° 18′ S, long. 60° W, and in lat. 54° 41′ S, long. 55° 12′ W. The present evidence of sedimentary strata is therefore of considerable geological interest.

Although there appears to be some doubt, as shown above, on the degree of reliance that may here be placed on certain species of Foraminifera generally taken to be precise Upper Cretaceous markers, in my opinion there is little doubt that, on the ground of the foraminiferal evidence, the Burdwood Bank beds include Upper Cretaceous (Senonian) strata, together with representatives of the Lower Tertiary succession. In the circumstances, and on account of the rather deep-water facies of the Foraminifera, it is perhaps not a matter for surprise that faunas of the two ages cannot be clearly separated.

The Burdwood Bank beds thus appear clearly as a direct continuation of those of Staten Island and Tierra del Fuego, as was believed by Suess. The latter beds are seen to have taken part in the continuation of the Andean folding, which has been discussed by authors under the ill-named title of the "South Antillean Arc"; Mr Wordie has agreed that it may better be referred to as the "Scotia Arc", since it surrounds the newly named Scotia Sea. This new evidence appears to strengthen the hypothesis that

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[1] *The Face of the Earth* (English Trans.), 1909, IV, p. 490.

South Georgia with its folded Cumberland Bay Series, probably in part at least of Cretaceous age, is part of the same arc of folding.[1]

The very numerous echo-soundings taken by the Discovery Expedition have been studied by H. F. P. Herdman,[2] and the results are of great importance from the geological standpoint. It appears now to be clear for the first time that the contour of the sea-bottom definitely fits in with the line of the Scotia Arc from Tierra del Fuego, through Burdwood Bank, Shag Rocks, South Georgia, Clerke Rocks, South Sandwich Islands, South Orkney Islands, to the South Shetland Islands and the Trinity Peninsula of Graham Land.[3] This trend is clearly marked on the new charts by the ridge, frequently irregular, which rises from the sea floor and, it seems, must reflect the geological fold structure. An equally important point is that there appears to be no room for any alternative arc, since the available soundings are set too close to allow of any appreciable ridges across the Scotia Sea farther west having been overlooked.

What may have been two abortive attempts to shorten the arc by closure farther west are perhaps indicated by, firstly, the south-eastward projection of the eastern end of the Burdwood Bank, which has no mapped counterpart on the south of the arc; and secondly, by the position and trend of South Georgia, which has a counterpart on the south of the arc indicated by the northerly double projection of the 3000 m. line. In neither case, however, can the ridges be regarded as more than a tentative effort of the folding, which never arrived at completion. In the former case, indeed, the projection is towards an area of greater than the usual depth in the Scotia Sea.

For suggestions and criticism of this paper I am much indebted to Dr Stanley Kemp, F.R.S., to Mr J. M. Wordie, and to Mr A. G. Brighton; and for much help in the determination of some of the Foraminifera I am greatly indebted to Mr A. Earland.

SUMMARY

Three bottom samples dredged by the Discovery Expedition yielded fossil Foraminifera of rather deep-water facies; some were obtained loose on the sea-floor and others were washed in the laboratory from fragments of green-grey shales, which also contained a few Radiolaria. Thirty-four species are recorded and six are figured, none is new; they include some considered to be of Upper Cretaceous (Senonian) age, and others probably from the Lower Tertiary. Previous records of the fossil Foraminifera

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[1] For recent discussions of this see O. Holtedahl, 1929, On the Geology and Physiography of some Antarctic and Sub-Antarctic Islands, *Sci. Res. Norwegian Ant. Exps.*, 1927–8, 1928–9, No. 3, pp. 104–17. 8vo, Oslo; and also O. Wilckens, 1932, Der Bogen der Südlichen Antillen (Antarktis), *Sitz. Naturw. Abt. Nieder-rhein. Ges. Natur- und Heilkunde*, 1930–1, *herausg. v. d. Naturhist. Ver. preuss. Rheinlande und Westfalens*, pp. 1–14 (separate), Bonn.

[2] H. F. P. Herdman, 1932, Report on Soundings taken during the Discovery Investigations, 1926–32, *Discovery Reports*, VI, pp. 205–36, pls. xlv–xlvii, Cambridge.

[3] Cf. T. Stocks, 1932, *Zeitschr. Ges. Erdkunde, Berlin*, pp. 198–208.

of the area are reviewed, and the regional stratigraphy is discussed. It is considered that the Burdwood Bank beds are clearly shown to be the continuation of those exposed on Tierra del Fuego and Staten Island, and a part of the (renamed) Scotia Arc of folding, which is continued on a trend precisely determined by the soundings to lie on the line of the Shag Rocks, South Georgia, Clerke Rocks, South Sandwich Islands, South Orkney Islands to the South Shetlands and Graham Land.

Note. Pebbles from Sts. 719 and 720 were submitted to Mr W. Campbell Smith for his opinion, and he kindly reports that in the sample from St. 719 he found a large number of dark brown (some almost black) pebbles rich in phosphate and containing fragments of Radiolaria. Most of these are slightly calcareous as well as phosphatic, and are rather like the phosphate nodules of Agulhas Bank preserved in the British Museum (Natural History).

In the sample from St. 720 he found similar phosphatic nodules, and also rounded pebbles of greywacke, quartz-plagioclase-porphyry (quartz-porphyrite of some authors), quartz-diorite, quartz-gabbro, hornblende-granulite, and a slaty rock with bands rich in clastic felspar. Such rocks must have been derived from a land mass. The "slate", "greywacke", quartz-diorite, and quartz-plagioclase-porphyry can be matched almost exactly with rocks from points on the west of Tierra del Fuego, e.g. a similar quartz-diorite occurs on Hermite Island. He found no fragments of volcanic rocks in either sample.

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FAECAL PELLETS FROM MARINE DEPOSITS

By

HILARY B. MOORE, B.Sc.

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FAECAL PELLETS FROM MARINE DEPOSITS

By Hilary B. Moore, B.Sc.

(Text-fig. 1)

In many accounts of marine deposits, mention is made of small ovoid bodies, of more or less the same consistency as the matrix in which they are found, and forming up to 30 per cent and in rarer cases as much as 100 per cent of the deposit.

Since these bodies are found in both recent and fossil marine deposits, and are of world-wide occurrence, and since various theories have been suggested as to their origin, it is thought desirable to bring together here the facts which are known as to their nature and occurrence.

Buchanan (1890), in an account of some mud taken off Arran in the Firth of Clyde in 1878, describes elongated pellets which could be separated from the ground-mass of the mud by elutriation. He rightly ascribes to these pellets an animal origin, but introduces an error which has been followed by several subsequent authors in saying that they are the faeces of ophiuroids. The error arose from the fact that he took the mud by means of an iron bucket which skimmed the surface of the mud. This collected at the same time both the surface mud with its contained pellets, and a large number of ophiuroids, probably *Amphiura chiajii*. He therefore drew the conclusion that these were responsible for the production of the pellets, which, he says, were formed by the trituration of sand grains in their stomachs. In the same paragraph, however, he states that in those particular muds there is practically no sandy material. In any case, examination of *Amphiura chiajii* shows that it does not form pellets of either this, or any other regular shape, and that its excreta are in very much larger masses than the mud pellets. Further, it has since been demonstrated (Moore, 1931) that the pellets in these particular muds are formed by Maldanid worms. And the worms themselves are rarely taken in any quantity by an instrument which merely skims the surface of the mud.

Buchanan (1890) further records a similar mud taken in 1879 in the Sound of Rasay in 155 fathoms, and again he says: "Sticking to the outside of the bag were many large ophiuroids, which will account for the coprolites (Extract from the Deck Book of the Steam Yacht 'Mallard', 1879)." He continues: "Later, in the year 1886, when in charge of the expedition to survey the Gulf of Guinea, in the steamship 'Buccaneer', I found the same thing almost universal all along the African coast, and developed in the most remarkable manner on the coast flat within a considerable radius of the mouth of the river Congo. Here it was necessary to introduce new designation for muds, and in this district, the most frequent entries in the deck book as to the nature of the bottom are 'cop.m.', meaning coprolitic mud. These so-called coprolites were almost jet-black, and of the size of mouse droppings, and they were covered with the same substance in flocculent form, or were free from it, according to the scour of the tide in the locality. It was best developed in comparatively shallow water, in a depth of 50 fathoms, when the large ash bucket, to the use of which I found it convenient to revert, came up full of these coprolites, without any flocculent matter whatever. All along the coast the mud of the locality was moulded in a similar way, though it was not so striking. When the course of the cruise took us across the open ocean to Ascension, and thence northwards, we were able to trace the transition of the more earthy shore coprolites into the mineralised and glauconitic pelagic ones". I think the last sentence means that pellets found in the deeper deposits were formed from material of pelagic origin, and not by pelagic animals.

Murray and Renard (1891), in describing the bottom samples of the Challenger Expedition, say: "In examining the samples of Blue Muds, and especially those near the mouths of rivers, many oval-shaped bodies, about 0·5 mm. in length, were observed. These were described by some observers as Foraminifera. Mr Murray, after numerous observations, came to the conclusion that they were mostly the excreta of echinoderms, principally of holothurians. When these pellets are voided by the animal they are covered by a slimy substance; many of them may indeed be united in a chain. In some deposits this dung is exceedingly abundant, but as a rule it is impossible to recognize these oval bodies in any of the organic oozes, and in the Red Clays only some doubtful specimens have been met with. They appear to fall asunder when the deposit is granular, like a globigerina ooze, or when long exposed without being covered up, as in the case of red clays".

There are two arguments against the supposition that these are holothurian pellets. In the first place the theory entails the existence in considerable numbers and with a world-wide distribution of a small holothurian, about 2 cm. long. That size is arrived at from the diameters of known holothurian pellets, a *Holothuria nigra* 20 cm. long having a pellet 4 mm. in diameter, and a *Cucumaria hyndmani* 5 cm. long having pellets with a diameter of 0·75 mm. Such a holothurian is at any rate not present in the Clyde, where these pellets are very abundant (Buchanan, 1890; Moore, 1931). In the second place, all the holothurian pellets which I have seen are either in the form of rods, or else of rods constricted at more or less regular intervals by deep clefts, the rods tending to break into short lengths at these constrictions. Also they are characterized by their extreme fragility, being much more friable than the ovoid pellets of the mud, which remain firm after a hundred years (Moore, 1931) and may even fossilize. Murray himself confirms their friability. Further, the pellets into which the holothurian faecal rods may break are not ovoid, as are the pellets found in these deep-water deposits, but rather cylindrical, with slightly rounded ends. This shape seems to be fairly constant for the holothurian pellets, as is the ovoid shape for the pellets from the deposits, and it has been shown (Moore, 1931 *a*, 1931 *b*) that such differences of shape are, when constant, of definite specific importance.

Murray and Philippi (1908) describe and figure a sample from off the mouth of the

Congo, the description being as follows: "Viele ovale gerundete Körper, warscheinlich die Exkremente von Echinodermen. Bei einigen von ihnen lässt sich deutlich Glaukonitsierung beobachten. Sie variieren in der Länge von 0·4–0·8 mm., in der Breite von 0·2–0·6 mm." They figure also a pteropod ooze in which there are some similar coprolites. On p. 103 they say: "Den wichtigsten und interessantesten Teil dieser Probe bilden die ovalen Körperchen welche von Sir John Murray für Exkremente von Echinodermen gehalten werden. Sie wechseln in der Färbung von grau zu braun und dunkelgrün. Sie wurden bereits von der Challenger Expedition erwähnt, und sind seitdem besonders durch Buchanan aus dem Golf von Guinea und von der Kongomündung bekannt geworden. Buchanan konstatierte, dass mancherorts in einer Tiefe von 50 Faden die ganze Anlagerung aus diesen Exkrementen besteht, und gebrauchte dafür die Bezeichnung 'Coprolitic Mud'. Diese Exkremente fanden sich bisher nur in tonigen Ablagerungen in der Nähe des Landes, besonders an der Mündung grosser Ströme".

Vaughan (1924) has figured and compared similar pellets from the Bahamas, and oolites from the same region. He says (p. 327): "For some time I thought the ellipsoidal aggregates in the fine-grained muds were to be considered oolite grains, for in external features they are very similar, but the grains in the mud do not exhibit the concentric structure of the oolite grains....However, the cores of the oolite grains are similar to the grains in the muds, and it may yet be shown that the grains in the mud represent a stage in the formation of oolitic limestone....The origin of the ellipsoidal grains is a puzzle. They resemble in size, form and general structure, glauconite and greenalite grains, and it is probable that when their formation is explained, the explanation will be of wide application". In his photographs of sections of pellets from the Bahamas there is, as stated, no trace of concentric structure, nor of localization of any particular material, but there appears to be a darker region round the outside of the pellet, presumably corresponding to a region of slightly finer material, possibly to some extent cemented with mucus or some other material. If this is the case they are similar in structure to the pellets described from the Clyde (Moore, 1931, 1931 *a*; Galliher, 1932, fig. 2).

Takahashi and Yagi (1929) describe the distribution of similar pellets in various localities in Japan. With the exception of Kasumiga-Ura, which is a nearly fresh-water lake, the pellets were found only in marine deposits, and not in fresh water. The pellets formed in some cases as much as 5 per cent of the deposits, and are described as elongated ellipsoidal, with a diameter of 0·5–1·4 mm. They were rather soft and friable, and varied in colour from light grey to dark green, the apparent density varying from 1·6 in the grey to 2·2 in the green ones. In section they appeared, with rare exceptions, to be homogeneous. Takahashi and Yagi compare these pellets with very similar structures from Tertiary deposits, and trace the probable course of glauconization in the recent pellets. With regard to the origin of these pellets they suggest that these are probably the faeces of some mud-eating animal. It is interesting to note that some few of their pellets, although ovoid in outline, had helicoidal cores. Although I have not so far met with the pellets of any animals which quite correspond with this type, those of the mollusc *Aplysia punctata* have a similar outer layer, enclosing an inner pellet of different shape, while those of many molluscs have spiral groovings on the surface, and in extreme forms the pellet may be in the form of a spirally twisted rod. It is easy to imagine the conjunction of these two types giving rise to an ovoid pellet with a spiral core, as described above.

Galliher (1931) has described, under the name of "Sporbo", structures which are apparently fossilized pellets of this same ovoid shape, from Miocene oil shales in America, and in a later paper (1932) he compares these with similar recent pellets from the Clyde. With the exception of hardening, and in many cases pyritization of the former, they appear to be very similar.

Thorp (1931) describes three stations off the coast of Panama, on the Atlantic side, in depths of 3595, 2131 and 3445 m. respectively, in which pellets form 26·1, 38·1 and 44·1 per cent of the mud; and of thirty-two stations described by him from the western North Atlantic and Caribbean Sea, sixteen are recorded as containing such pellets. With regard to the origin of these, however, he is very doubtful. He says: "The size and shape of the individual ovoid suggest an organic excrement but the preservation for any length of time of such an object appears doubtful. Bacteria would find nourishment in the unassimilated food of higher organisms. As a result most of the remains would be converted into gaseous and water-soluble products. These in turn would be dispersed by the sea water. It appears more probable that chemical and physical aggregation is responsible for the formation of these objects".

In the case of the pellets found in the Clyde it has been definitely shown that they are animal products (Moore, 1931), and furthermore that they are able to retain their form as well as their differentiation from the surrounding mud for periods of at least a hundred years. At the end of this period they are quite as definite as they were when they were first formed, and there is no reason to suppose that any new agencies come into play to cause their breakdown after that time. At any rate bacteria are known to be abundant throughout the whole of the time, and at all depths in the mud (Lloyd, 1931).

In the Discovery material there was a type of pellet which was very abundant in some of the plankton nettings. Samples were examined from Stations 549, and WS 399, and the pellets in them were almost certainly those of *Euphausia superba*, which is very abundant in the plankton there. They agree in form with those in the gut of the animal, as well as with those described from other euphausids from the Clyde (Moore, 1931 *a*). No pellets of this type were observed in any of the bottom deposits, which was probably due to their quick breakdown as was the case in the Clyde, where pellets of euphausids and of *Calanus finmarchicus* could be seen abundantly on the extreme surface of the mud, but were never recognizable below the surface.

The pellets from the bottom deposits fall into two classes, rod-shaped and ovoid, of which the latter were numerically by far the most abundant. They occur at various stations and at all depths, and though their size and shape vary slightly, they are all of the same general type. The details of these are given in the table on page 24. Since this ovoid shape of pellet is common to very many kinds of animals, it is probable that the ones found in the deposits represent the faeces of several different species.

Smooth rod-shaped pellets with a diameter of up to 0·15 mm. were found abundantly at St. WS 144, and in smaller numbers at St. WS 502. A single specimen of a simply sculptured rod was found at St. 375. It consisted of a rod, circular in section, with a single groove along one side (Fig. 1 *a*). In transverse section it appears to be composed largely of diatom remains, more so in fact than the mud from which it came, or the ovoid pellets found there, so that it must be the pellet of a selective feeder. I would suggest further that it is probably the pellet of a mollusc, although none are at present known of quite this type.

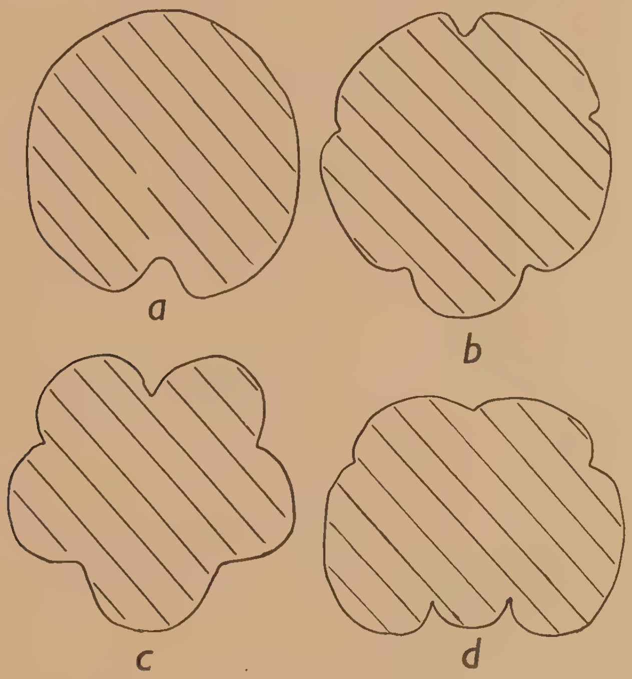

Fig. 1. Transverse sections of pellets from marine deposits. *a*, Pellet of a mollusc ?, from St. 375. *b*, Pellet of *Nucula* sp., from St. WS 144. *c*, Pellet of *Nucula tenuis*, from the Clyde. *d*, Pellet of *Nucula moorei*, from the Clyde.

A second and more complexly sculptured type of rod-shaped pellet was found abundantly at St. WS 144, and consisted of a rod up to 0·16 mm. in diameter with a series of longitudinal grooves on the surface. In transverse section (Fig. 1 *b*) this also appeared to be formed almost entirely from diatom remains, and may also therefore be classed as a probable selective feeder. So few pellets have as yet been described that it would be unreasonable to attempt to identify an unknown pellet with any given animal without a considerable knowledge of the fauna of the locality. But this pellet in all respects resembles those at present known for the genus *Nucula*, and it is at least reasonable to advance the possibility of its belonging to this genus. *Nucula* pellets are all rods with longitudinal grooves; and all the species which I have so far examined may be differentiated by specific differences in the number and arrangement of these grooves (Moore, 1931 *a*). The pellets from WS 144 have five grooves in common with *N. tenuis* (Mont.) and *N. moorei*, Winckworth, which are shown in transverse section in Fig. 1 *c*, *d* for comparison. The grooves are fairly, but not extremely, deeply cut, and in this they resemble those of *N. moorei*. But the ridges are all of about the same size, and the mid-ventral ridge is very prominent, as in *N. tenuis*. It does not belong therefore to either of these species, and if it does belong to a *Nucula* it probably belongs to one whose pellets have not yet been described.

Station	Position	Depth: m.	Amount of material examined: cc.	Number of pellets per cc.			Notes on abundance and size of pellets
				Ovoid	Simple rods	Sculptured rods	
369	59° 17¼′ S, 26° 57′ W	1766	7·0	7·4	0	0	A few large and some smaller ovoid type present. Diam. 0·55 mm., length 0·95 mm., length/breadth 1·75; smaller sizes down to 0·25 mm. long.
372	57° 57′ S, 29° 53′ W	292	—	0	0	0	No pellets found.
373	58° 00′ S, 33° 44′ W	2515	0·65	1·5	0	0	A very few ovoid type present. Diam. 0·12 mm., length 0·26 mm., length/breadth 2·2.
375	57° 47′ S, 40° 49′ W	3665	—		0	1	Ovoid type abundant, but no count made. A single specimen found of a rod-shaped type with one longitudinal groove.
417	38° 09′ S, 17° 45½′ E	4778	—	0	0	0	No pellets found.
425	34° 50′ S, 26° 41½′ E	4107	—		0	0	Ovoid type abundant, but no count made.
WS 144	54° 08′ S, 36° 10′ W	279	0·42	52	179	79	Only a few ovoid type present, but plain and sculptured rods abundant. Ovoids, diam. 0·28 mm., length 0·46 mm., length/breadth 1·64; plain rods, diam. 0·12 mm.; sculptured rods, diam. 0·26 mm.
WS 240	51° 55′ S, 65° 10′ W	141	—	0	0	0	No pellets found.
WS 248	52° 40′ S, 58° 30′ W	210	4·95	0	0	0	No pellets found.
WS 374	55° 09′ S, 40° 00′ W	3226	2·25	0	0	0	No pellets found.
WS 394	62° 51′ S, 60° 40′ W	274	2·25	0	0	0	No pellets found.
WS 403	59° 40′ S, 64° 35′ W	3721	7·0	0	0	0	No pellets found.
WS 474	61° 03′ S, 56° 42′ W	2813	4·15	0	0	0	No pellets found.
WS 501	64° 52′ S, 63° 58′ W	583	5·25	0	0	0	No pellets found.
WS 502	69° 43′ S, 99° 38′ W	4224	1·0	148	98	0	A few large ovoid type, and a few smooth rods. Rods diam. 0·05–0·15 mm., and in lengths of 3 or 4 times the diam.
WS 506	70° 31′ S, 81° 36′ W	584	0·4	175	0	0	A lot of ovoid type present, but so broken that the count might easily represent 1/10 only of the true number. Lengths up to 0·5 mm.
WS 519	52° 09½′ S, 53° 21½′ W	2270	1·5	3·3	0	0	A few large ovoid type present. Diam. 0·24 mm., length 0·47 mm., length/breadth 1·95.
WS 521	52° 41′ S, 47° 14′ W	3780	3·15	0	0	0	No pellets found.

The estimates of the numbers of pellets per cubic centimetre, given in the table, must be taken as only very rough approximations. The volumes of mud on which they are based are the volumes of a portion of the deposit, shaken up in distilled water, and allowed to settle for 24 hours at about 15° C. The highest number of the *Nucula* type of pellet found was 79 per cc., which is about three times the highest value found in the Clyde (Moore, 1931, p. 355); but the highest value for the ovoid type—179 per cc.—is far lower than the value of 3400 per cc., from Loch Striven.

The facts known with regard to the formation of these oval pellets may be summarized as follows. They are of world-wide distribution, occurring in recent deposits in depths of from 0 to over 4000 m., and in conditions varying from almost fresh to salt water, and also in certain fossil deposits. Although more than one type is found (and E. M. Thorp [personal communication] states that there are two common and easily distinguished forms in the West Indian region), yet there is a simple oval type which occurs abundantly in a number of localities. In structure they are composed of the same material as the mud in which they are found, although naturally limited to the smaller particles of that mud. They show no trace of concentric structure as would be expected if they were oolite-like aggregates. Further, their occurrence as central cores for some oolites suggests an entirely different origin from that of the outer layers of the oolites. The possibility of their production by the rolling together of the surface layers of the mud under the influence of currents is negatived by their comparative firmness, and also by the fact that they may form as much as 100 per cent of the mud, with no interstitial fine material at all. It is hard to see how such rolling could proceed so far as to remove the whole of the fine material. It might, however, produce such a deposit composed entirely of pellets by washing out all the fine material from between the heavier pellets. Such a process would not account though for the presence in the mud of patches, such as were occasionally found in the Clyde, where the whole of the mud had been converted into pellets, these patches being quite small in extent, and sometimes surrounding the mouth of the burrow of a worm (Moore, 1931, p. 354, fig. 11). In relation to the latter observation it is interesting to note that Galliher also (1931, p. 265) states that the fossil "sporbo" occurs "in lenses parallel with the bedding and in small oval pockets".

In favour of the animal origin of these pellets is the fact that the pellets from the different localities appear to be similar, and that those from the Clyde have been definitely shown to be of animal origin, and that Maldanid worms, which are abundant in these Clyde muds, shed a pellet identical in nature with the pellets found in the mud.

Although the pellets of a number of littoral and shallow-water animals are now known, nothing is as yet known of the pellets of any very deep-water animals (except for one or two Anomura). The nature of the ovoid pellets suggests that they are those of either polychaetes or molluscs; they are not likely to be crustacean in origin (see Moore, 1932, for general description of crustacean pellets). It remains, therefore, to obtain specimens of the fauna of the muds in which these pellets are most abundant, and to examine their gut contents to see whether similar pellets can be found in them.

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FORAMINIFERA

PART II. SOUTH GEORGIA

By

ARTHUR EARLAND, F.R.M.S.

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NOTE

Owing to illness my colleague Edward Heron-Allen was unable to take as large a share as usual in the preparation of this Report. At his own request, and against my wish, his name is omitted from the authorship.—A. E.

FORAMINIFERA

PART II. SOUTH GEORGIA

By Arthur Earland, F.R.M.S.

(Plates I–VII, text-figs. 1–3)

INTRODUCTORY NOTE

The first part of this Report dealt with the bottom deposits from the Falkland Islands and the adjacent area. The present Report deals with the island of South Georgia and the outlying Shag Rocks, situated some 800 miles to the eastward of the Falklands in the Southern Ocean.

Although there is no great difference in latitude between the position of the Falkland Islands (51°–52° 30′ S) and South Georgia (54°–55° S), it would be difficult to find two areas so nearly in the same latitude presenting greater contrasts. The Falklands, lying on the Continental Shelf of South America, are surrounded by a wide area of shallow water with generally sandy bottom deposits, and, owing to the influence of the warm Pacific water coming through the Drake Strait, are entirely free from ice and present a fauna of a distinctly cool, temperate type. South Georgia, on the other hand, lies outside the influence of the Pacific warm water and, surrounded by the cold Antarctic current flowing northwards, is within the region of pack-ice. The island rises more or less abruptly from deep water, so that the 100-fathom line lies quite near the coast. The land area is mountainous and ice-covered, and there are many glaciers. These influence the formation of the coastal deposits which, in contrast with the sandy deposits of the Falkland area, are almost universally composed of a tenacious blue mud of which Diatoms, so abundant in the surface waters of the Antarctic seas, form a notable constituent. As a general result the bottom faunas of the two areas are very different. The majority of the species which are dominant in the Falkland area are rare, and sometimes absent in South Georgia. The local fauna in coastal waters is of a distinct type including many species new to science, while in the deeper water it is more or less identical with that found at similar depths in all seas. Following the general rule that the Arenacea favour cold water, this group plays a larger part than usual even in the shallow coastal areas.

PREVIOUS WORK IN THE AREA

South Georgia represents practically virgin ground so far as the Foraminifera are concerned. It was not touched by the Challenger, Scotia or Terra Nova Expeditions, and, although the members of the Quest Expedition did much work on the island, the paper on "Deep Sea Deposits and Dredgings" by Miss A. Vibert Douglas[1] deals only with the physical characters of the deposits. Four species of *Globigerina* only are mentioned (*G. dubia*, *rubra*, *bulloides*, *sacculifera*), the last of which is almost certainly misidentified.

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[1] *Report on the Geological Collections made during the voyage of the "Quest" on the Shackleton-Rowett Expedition to the South Atlantic and Weddell Sea in 1921–1922.* British Museum (Natural History), 1930, pp. 145–56.

MATERIAL EXAMINED

Bottom samples were received from about ninety stations, over fifty of them being fairly evenly distributed in the shallower coastal waters, while the others consist of lines of soundings run out in various directions into the very deep water surrounding the island.

The vast majority of the samples consisted of sounding materials only, the quantity rarely exceeding 25 cc., and in most cases much less. Almost without exception these soundings consisted of tenacious mud of shades varying from grey and blue to almost black. They were treated by washing on a silk sieve of 200 meshes per linear inch, and the residues were generally very small, seldom more than a few cc. The muds, which were preserved in spirit, were frequently refractory, in which case the method followed was to dry thoroughly after a preliminary washing, break down the dried residue with boiling water and wash again. In a few instances only it was found necessary to use soda to break down the deposit.

The chief difficulty in the cleaning process lay in the abundance of Diatoms. Apart from the smaller forms which passed readily through the sieve, larger species, notably *Fragilaria antarctica*, *Cocconeis imperatrix* and *Cestodiscus gemmifer*, were often present in such numbers as to form a felt in the sieve. It was not possible to separate them from the smaller and lighter species of Foraminifera, such as *Virgulina*, which were often equally abundant, and their presence added to the difficulty and monotony of the examination of the residues. Another Diatom, presumably *Nitzschia* sp., which was equally abundant and the principal cause of the felting in the sieves, could be more or less eliminated after cleaning, as it separated from the dried material when shaken in a tube, forming masses like cotton-wool.

No great variety of species can ever be expected in shallow-water soundings. As the Foraminifera exist mainly in the surface layer, the area sampled by the sounding tube is not large enough to ensure much of a catch. The large arenaceous species which, from other sources, are known to be present, are not in sufficient numbers to ensure capture, and when taken were generally fragmentary.

The examination of these shallow-water soundings therefore proved a long and monotonous task. Station after station yielded approximately 20–30 species, mostly identical. Now and then the occurrence of a species not previously observed gave some encouragement to proceed with the work.

The typical species inhabiting the coastal waters occur in nearly every sample, material from each station as a rule furnishing one or two other species of less constant distribution. Broadly speaking, the typical species are as follows (those marked * may be regarded as being peculiarly characteristic and constant):

Ammodiscus incertus
Cassidulina crassa
**Cassidulina parkeriana*
**Cassidulina subglobosa*
**Ehrenbergina crassa*
**Globigerina dutertrei*

*_Globigerina pachyderma_
Glomospira gordialis
Haplophragmoides canariensis
*_Lagena biancae_
*_Miliammina obliqua_
*_Miliammina oblonga_
*_Nonion depressulum_
*_Nonionella iridea_
Pullenia subcarinata
Psammosphaera fusca
Pulvinulina karsteni
Pulvinulina peruviana
*_Reophax subfusiformis_
Textularia tenuissima
Tholosina vesicularis
*_Trochammina malovensis_
*_Uvigerina angulosa_
Virgulina bradyi
*_Virgulina schreibersiana_

Very fortunately I received additional material from other nets, frequently from stations at which soundings had also been taken. This corrected the impression, which might otherwise have been formed, that the South Georgian fauna was limited and scanty. The additional material consisted of five dredgings, four samples of trawl residues, and fourteen gatherings taken from nets which had touched bottom or had been attached for other purposes to the trawl. This is not a novel method of collecting Foraminifera; it has been used with great success on muddy bottoms by both the Scottish and Irish Fisheries Boards. The trawl boards throw up the surface mud which passes through the coarse mesh of the net, leaving behind the larger Foraminifera and sufficient mud to supply the smaller species also.

These net and trawl residues yielded a surprisingly long list, including several new genera and species. The evidence obtained from dredgings and soundings indicates the sea-bottom in the coastal areas of South Georgia to be a surface of tenacious mud, loaded with Diatoms derived from the surface waters, and having an abundant fauna of small Foraminifera limited in species, and a more sparsely distributed but characteristic fauna of larger species. Many of these are mud-eaters, and find an abundant food supply in the Diatoms, masses of which are found inside their tests. Conditions are so similar everywhere that there is less variation observable than is usually the case.

Owing to the fact that the area has not been previously investigated there is quite a formidable list of new forms, including four distinctive new genera *Gordiospira*, *Pelosphaera*, *Armorella* and *Hippocrepinella*, besides *Miliammina*, which we described from South Georgia in 1930. As regards the last, it is now known that its range extends both southwards into the Antarctic and northwards to Tristan d'Acunha (St. 6) and South African coastal waters (St. WS 4), but I am not at present able to state whether any of the other genera, except *Armorella*, extend outside the South Georgian area.

The gatherings from depths outside the coastal waters do not call for many comments. They include *Globigerina* ooze, diatomaceous ooze, and a few soundings characterized by abundant Radiolaria, though not in sufficient numbers to constitute a true radiolarian ooze. Their foraminiferal faunas are varied but present no special characteristics. It is perhaps noteworthy that, even in the deepest of the soundings, pebbles and sand grains of all sizes are usually present, probably derived from floating ice.

In conclusion, it may be stated that South Georgia appears, on the evidence at present available, to possess a somewhat characteristic foraminiferal fauna of its own. Dismissing the numerous species which have a world-wide distribution under similar conditions of depth and temperature, it possesses many forms unknown or comparatively rare elsewhere. It has little apparent connection with the Falkland fauna; apart from widely distributed species common to both areas, very few of the Falkland species proper are found in South Georgia, and those few very rarely. How far the examination of the material received from the Antarctic Islands will modify this view of the isolation of the South Georgia area, I cannot yet say, but from the present state of the work it would seem that the two regions are not closely connected, although many South Georgian species occur in the Antarctic area, as might be expected from the similarity of physical conditions.

A list of the stations worked over is as follows:

STATIONS MADE BY THE R.R.S. 'DISCOVERY'

13. TS 589.[1] (See Fig. 2.)[2]
3. iii. 26. 5·7 miles N 49½° E of Jason Light. Sounding rod, 143 m.
About 15 cc. of tenacious dark slate-coloured mud. Residue of pebbles and dark sand grains of all sizes, Diatoms, spicules and very few Foraminifera, all of common species.

14. TS 544. D II.[3]
3. iii. 26. 15·4 miles N 44° 30′ E of Jason Light. Sounding rod, 260 m.
About 15 cc. of dark greenish brown mud yielding a residue of dark sub-angular sand grains, a few sponge spicules, Radiolaria and scanty Foraminifera; *Miliammina oblonga*, *M. obliqua* and *Ammobaculites americanus* being the only species occurring in any numbers.

15. TS 547. D I.
3. iii. 26. 25 miles N 45° 30′ E of Jason Light. Sounding rod, 191 m.
A very small sample of grey mud, mainly diatomaceous. Sixteen species of Foraminifera were recorded, all of which, except *Bulimina fusiformis*, were represented by one or at most two specimens.

16. TS 549. E I.
3. iii. 26. 36·5 miles N 46° E of Jason Light. Sounding rod, 727 m.
A few cc. of slate-coloured mud yielding a residue of angular sand grains, Diatoms, Radiolaria and a few Foraminifera, including a specimen of *Lagena spumosa*.

17. TS 550. E I.
4. iii. 26. 46 miles N 46° E of Jason Light. Sounding rod, 1900–1950 m.
A few pebbles and some fine sand with very few Foraminifera.

20. TS 539–540. D I.
4. iii. 26. 26·5 miles N 54° E of Jason Light. Sounding rod, 210 m.
Two samples:
(1) About 12 cc. tenacious slate-brown mud.
(2) About 10 cc. slate-green mud.
The residues were similar, angular sand grains with Diatoms and few Foraminifera, *Miliammina* and *Virgulina* being dominant.

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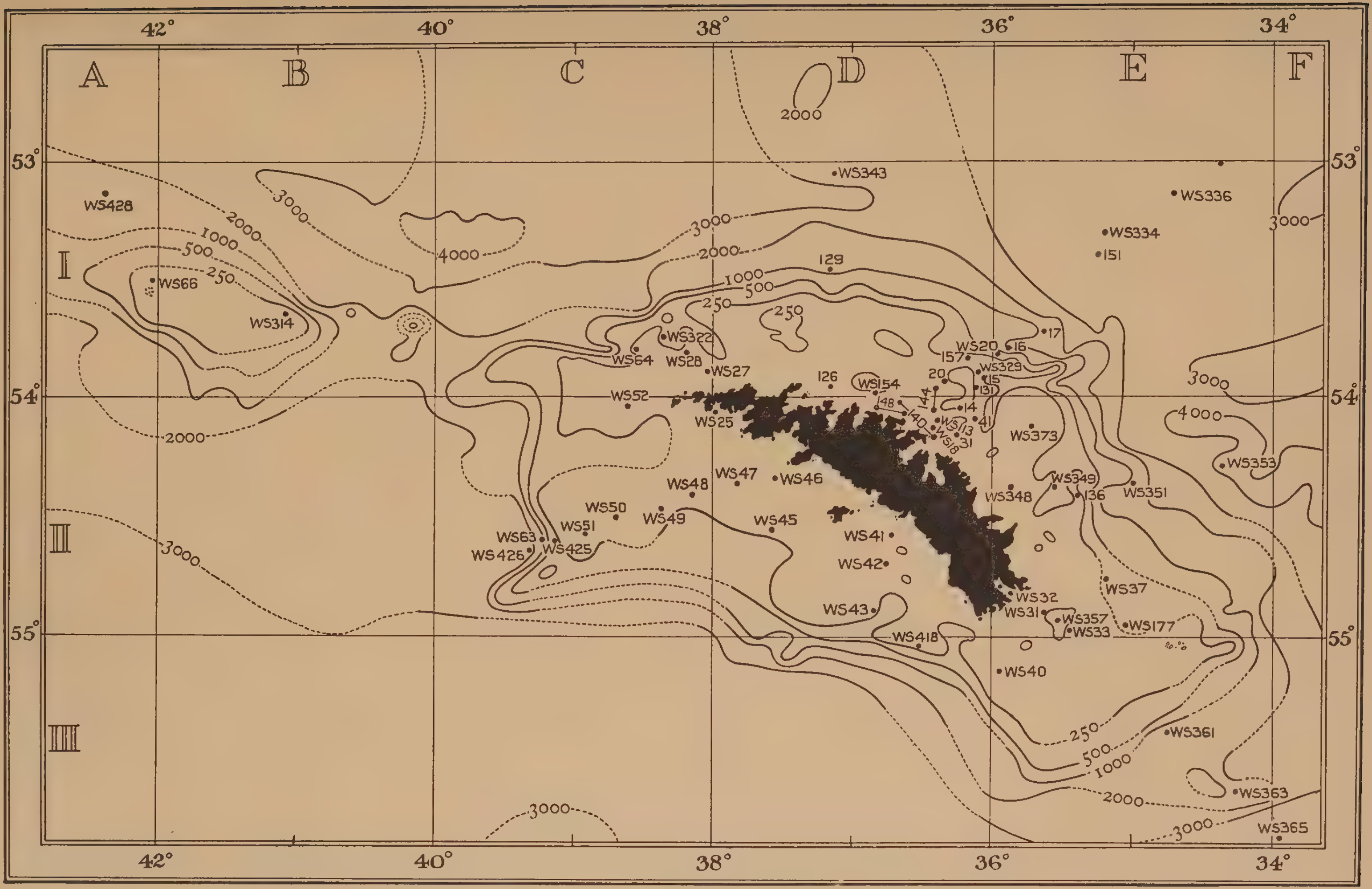
[1] These numbers refer to the station slides in the Heron-Allen and Earland collection in the Natural History Museum.

[2] This reference is to Fig. 2, p. 35, Chart of Cumberland Bay, South Georgia.

[3] These numbers afford reference to the positions of the stations as shown in Fig. 1, p. 33.


42°
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38°
36°
34°
A
B
C
D
E
F
53°
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I
II
III
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WS66
WS314
WS343
WS336
WS334
151
129
17
WS20
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WS329
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WS154
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WS349
136
WS351
WS353
WS361
WS363
WS365
250
500
1000
2000
3000
4000

Fig. 1. Chart of South Georgia showing the area within which most of the Foraminifera included in this Report were obtained. Bathymetric contours in metres.

23. TS 592. (See Fig. 2.)

14. iii. 26. 5·3 miles N 44° E of Merton Rock. Sounding rod, 228 m.

About 10 cc. of tenacious slate-coloured mud. Residue mainly Diatoms and sponge spicules, with numerous Foraminifera of a limited number of species. *Cassidulina parkeriana* was very common, *Miliammina oblonga*, *M. obliqua* and *Virgulina schreibersiana* common, the few other species mostly very rare.

27. TS 596–8. (See Fig. 2.)

15. iii. 26. 3·3 miles S 44° E of Jason Light, West Cumberland Bay. Dredge, 110 m.

A quantity of coarse black angular sand with Polyzoan and Echinoderm debris. Abundant Foraminifera of the larger species: *Ammobaculites americanus* very common; *Tholosina bulla*, *T. vesicularis*, *Haplophragmoides canariensis*, all common; *Hyperammina subnodosa* and *Vanhoeffenella gaussi*, frequent; *Armorella sphaerica*, *Pelosphaera cornuta*, rare.

28. TS 599–600 A. (See Fig. 2.)

16. iii. 26. 3·3 miles S 45° W of Jason Light, West Cumberland Bay. Sounding rod, 168 m.

About 14 cc. of tenacious slate-coloured mud yielding nothing but Diatoms and some *Miliamminae*. Another sounding (STB) of about 8 cc. of similar mud from 65 m. yielded sand, Diatoms, many *Miliamminae* and a few specimens representing five other species of Foraminifera.

A sample of 7 cc. of coarse black sand from a dredging at 168 m. contained a few Foraminifera, including *Hippocrepinella hirudinea*.

29. TS 600 B. (See Fig. 2.)

16. iii. 26. 5·9 miles S 51° W of Jason Light, West Cumberland Bay. Sounding rod, 23 m.

About 13 cc. of tenacious dark slate-coloured mud yielded a residue of fine sand and mud pellets, very few Diatoms, and fewer Foraminifera, *Psammosphaera parva* and a single specimen only of *Bulimina marginata* being recorded.

30. TS 601–2. (See Fig. 2.)

16. iii. 26. 2·8 miles S 24° W of Jason Light, West Cumberland Bay. Sounding rod, 251 m.

Fifteen cc. of tenacious dark blue mud, yielding only a fractional residue of Diatoms, spicules and Foraminifera, including *Textularia tenuissima*. A quantity of muddy washings from dredge residues, largely worm tubes, yielded about forty species of the smaller forms, including *Ehrenbergina pupa* very rare, *E. crassa* frequent, and a single *Tubinella funalis*.

31. TS 555. D II.

17. iii. 26. 13·5 miles N 89° E of Jason Light. Sounding rod, 220 m.

About 10 cc. of tenacious slate-coloured mud. Residue of dark sand grains, many otoliths and Diatoms, some Radiolaria and a few Foraminifera of the commoner species. *Miliammina oblonga*, *M. obliqua*, *Virgulina schreibersiana* and *Nonionella iridea* all common, *Tholosina vesicularis* frequent, all other species rare.

41. TS 557. D II.

28. iii. 26. 16½ miles N 39° E of Barff Point. Sounding rod, 272 m.

About 15 cc. of tenacious olive-brown mud. Residue mainly of Diatoms and fine sand grains. A few Foraminifera, of three species only: *Ammobaculites rostratus*, *Ehrenbergina crassa*, *Miliammina obliqua*.

42. TS 588. (See Fig. 2.)

1. iv. 26. Off the mouth of Cumberland Bay. Sounding rod, 204 m.

About 12 cc. of dark slate-coloured mud. Residue of sand grains, Diatoms and a few Foraminifera of the commoner species.

45. TS 593–4. (See Fig. 2.)

6. iv. 26. 2·7 miles S 85° E of Jason Light. Nets on trawl, 238–270 m.

Muddy trawl residues, largely consisting of sponge spicules in a felted mass with abundant Diatoms and many Foraminifera. *Biloculinae* of several species, *Pelosina*, *Hippocrepinella hirudinea* among the larger species were all very common; *Hyperammina subnodosa*, *Storthosphaera elongata*, *Ammobaculites bargmanni* common; a long list of the usual smaller species of varying degrees of rarity, *Virgulina schreibersiana* and *V. bradyi* being very common.

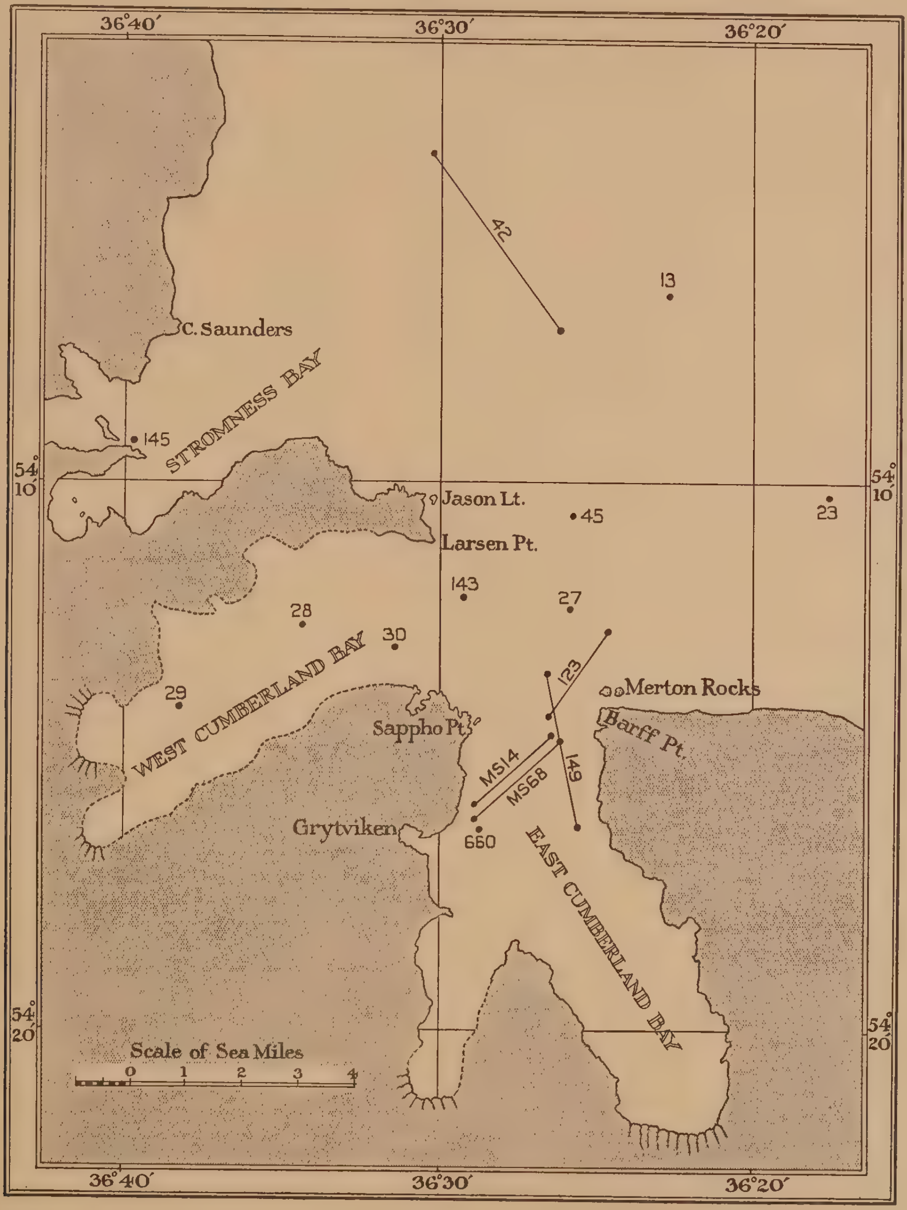
36°40′
36°30′
36°20′
54°10′
54°20′
C. Saunders
STROMNESS BAY
145
42
13
Jason Lt.
Larsen Pt.
45
23
143
27
28
30
29
WEST CUMBERLAND BAY
123
Merton Rocks
Barff Pt.
Sappho Pt.
MS14
MS68
149
Grytviken
660
EAST CUMBERLAND BAY
Scale of Sea Miles
0 1 2 3 4

Fig. 2. Cumberland Bay, South Georgia, and its approaches.

123. TS 603. (See Fig. 2.)

15. xii. 26. Off the mouth of Cumberland Bay. Sounding rod, 250 m.

Three and a half cc. of dark slate-coloured mud with a residue of Diatoms and a few *Miliamminae*.

Muddy trawl residues, mainly Crustacean and Echinoderm debris with coarse sand, yielded a large number of species, including *Hyperammina subnodosa*, *Ammobaculites americanus*, *Hippocrepinella hirudinea*, *Tubinella funalis*, *Armorella sphaerica* and all the commoner forms.

126. TS 529. D I.

19. xii. 26. 53° 58′ 30″ S, 37° 08′ W. Net touched bottom at 100 m.

About 70 cc. of dark angular sand and pebbles. *Miliammina oblonga*, *M. obliqua* and *Ehrenbergina crassa* very common. Many other interesting Arenacea, including *Webbinella limosa*, *Pelosphaera cornuta*, *Hippocrepinella hirudinea* and *H. alba*. Many large specimens of *Hyperammina subnodosa* were received preserved in spirit, having been selected on the ship.

129. TS 531. D I.

19. xii. 26. 53° 28′ 30″ S, 37° 08′ W. Sounding rod, 1001 m.

A few cc. of dark mud. Residue of a pebble, and fine angular sand with many Diatoms and Radiolaria but few Foraminifera, eight species only being represented.

131. TS 545–6. D I.

20. xii. 26. 53° 59′ 30″ S, 36° 11′ W. Sounding rod, 240 m.

Two samples:

(1) About 12 cc. of dark greenish brown mud, yielding as residue a pebble, dark angular sand grains, Diatoms, sponge spicules and Radiolaria. Foraminifera very rare except *Miliammina* and *Virgulina*.

(2) About 20 cc. of black sandy mud, yielding similar residue. Although Foraminifera were not numerous, a good many species were listed, but none of particular interest.

133. No TS.[1]

20–21. xii. 26. 53° 45′ 30″ S, 35° 46′ 30″ W.

A very small pelagic sample from a vertical haul of 270–100 m. (N 70 V) yielded a few *Globigerinae*, mostly *G. dutertrei*. *G. bulloides*, *G. triloba* and *G. conglomerata* were present in lesser numbers.

136. TS 560. E II.

21. xii. 26. 54° 22′ S, 35° 21′ W. Sounding rod, 246 m.

About 15 cc. of dark brown mud. The residue included some angular fragments of a schistose rock with sessile specimens of *Placopsilina cenomana*, *Tholosina vesicularis* and *Tolypammina vagans*. The finer residue consisted of angular sand with scanty Foraminifera, *Uvigerina angulosa* dominant, *Globigerina pachyderma*, *Virgulina schreibersiana* and *Cassidulina parkeriana* all common.

138. No TS.

22. xii. 26. 54° 17′ S, 34° 47′ W.

Small samples of pelagic material from two vertical hauls (N 70 V). The first, between 750 and 500 m., contained a few *Globigerinae* only, mostly *G. conglomerata* and *G. dutertrei*, the latter being less frequent. The second, between 500 and 250 m., consisted largely of Copepoda and Diatoms but yielded many *Globigerinae*, *G. conglomerata*, *G. dutertrei*, *G. bulloides*, *G. pachyderma*, their relative abundance being in the same order as listed. A few specimens of *Globorotalia scitula* were also seen.

139. No TS.

22–23. xii. 26. 53° 30′ 15″ S, 35° 50′ 45″ W.

A very small pelagic sample from a vertical haul (N 70 V), between 250 and 150 m., contained only a few specimens of *Globigerina conglomerata* and *G. dutertrei*.

140. TS 534. D II.

23. xii. 26. Stromness Harbour to Larsen Point, from 54° 02′ S, 36° 38′ W to 54° 11′ 30″ S, 36° 29′ W. Trawl, 122–136 m.

A small quantity of trawl refuse, mainly Echinoderm and sponge debris. Many interesting species of the larger *Arenacea*, *Pelosphaera*, *Hippocrepinella*, *Vanhoeffenella*, etc. Also many small species including *Patellina corrugata* and *Discorbis chasteri*.

143. TS 595. (See Fig. 2.)

30. xii. 26. 54° 12′ S, 36° 29′ 30″ W, off the mouth of East Cumberland Bay. Net on trawl, 273 m.

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[1] Where no TS (Station Slide) was prepared the Station has generally been omitted from Figs. 1, 2.

Five cc. of organic debris yielding a few Foraminifera including *Pelosina*, *Miliammina* and *Hippocrepinella*.

144. TS 536–8. D I, II.

5. i. 27. From 54° 04′ S, 36° 27′ W to 53° 58′ S, 36° 26′ W, off the mouth of Stromness Harbour. Nets on trawl, 155–178 m.

Fine washings from trawl, mud and organic debris. Residue largely of sponge spicules, Diatoms and dark sand. Many Foraminifera: *Tholosina bulla* and *T. vesicularis* abundant among the larger forms, and *Miliammina oblonga*, *M. obliqua*, *Virgulina schreibersiana*, *Cassidulina crassa*, *C. subglobosa*, *Haplophragmoides canariensis*, *Pulvinulina peruviana* and *P. karsteni* equally abundant among the smaller species.

145. TS 590–1. (See Fig. 2.)

7. i. 27. Between Grass Island and Tonsberg Point in Stromness Harbour. Trawl, 26–35 m.

Washings from trawl, organic debris of all kinds. Diatoms abundant but Foraminifera very few, though including such interesting species as *Turritellella shoneana*, *Cornuspira selseyensis*, *Gordiospira fragilis* and *Spirillina obconica*.

148. TS 533. D II.

9. i. 27. From 54° 03′ S, 36° 39′ W to 54° 05′ S, 36° 30′ W, off Cape Saunders. Nets on trawl, 132–148 m.

About 40 cc. of coarse organic debris. *Hyperammina subnodosa*, *Ammobaculites americanus* and *Reophax subfusiformis* very common. Many other large species, notably *Biloculinae* and Arenacea, but very few of the smaller South Georgian types, these presumably having been washed out. *Armorella sphaerica*, *Thurammina protea*, *Astrorhiza triangularis*, *Hippocrepinella* and *Pelosphaera* occur.

149. TS 604. (See Fig. 2.)

10. i. 27. Mouth of East Cumberland Bay. Nets on trawl, 200–234 m.

A quantity of muddy debris, mainly Annelid and Crustacean, yielded a long list of 104 species, no less than twenty-one of which were not recorded elsewhere in South Georgia. The majority were species of world-wide distribution and might reasonably have been expected in the area, but several forms being normally of warm water habitat, it was decided to reject the whole of the twenty-one species for fear that the gathering might have been inadvertently fouled by admixture with foreign material. *Armorella sphaerica* and *Pelosina fusiformis* were common.

151. TS 551. E I.

16. i. 27. 53° 25′ S, 35° 15′ W. Sounding rod, 3200 m.

About 5 cc. of grey mud with darker spots yielding a residue of dark sand, felted Diatoms and Radiolaria. The Foraminifera were few, but interesting, including *Cyclammina cancellata*, *Glomospira charoides*, *Ammochilostoma pauciloculata* and *Ammobaculites foliaceus*.

157. TS 541. D I.

20. i. 27. 53° 51′ S, 36° 11′ 15″ W. Sounding rod, 970 m.

About 3 cc. of dark mud yielding a residue of angular sand grains, Diatoms, Radiolaria and a few of the common species of Foraminifera.

660. TS 609. (See Fig. 2.)

0·6 miles E of Hope Point, East Cumberland Bay. Dredge, 216 m.

A quantity of slate-blue mud received dry in lumps. Difficult to clean and yielding very few Foraminifera. *Virgulina bradyi* and *V. schreibersiana* were the only species occurring in any numbers, but *Ehrenbergina crassa* and *Miliammina oblonga* were common. On the whole perhaps a typical South Georgian mud.

No station no. TS 554. E I.

19. ii. 26. 53° 00′ S, 34° 22′ 30″ W. Sounding rod, 2472 m.

About 12 cc. of pale grey mud—a Diatom ooze. Residue consisting of a few sand grains, Diatoms, Radiolaria, very few Foraminifera, nearly all arenaceous.

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WS 18. TS 542. D II.

26. xi. 26. 54° 07′ S, 36° 23′ W. Sounding rod, 113 m.

About 1 cc. of refractory slate-blue mud, which resisted disintegration. Treated with soda it yielded a residue of sand grains, mud pellets, Diatoms, sponge spicules and ten specimens of Foraminifera representing seven species, including one specimen of *Patellina corrugata*.

WS 20. TS 548. E I.

28. xi. 26. 53° 52′ 30″ S, 36° 00′ W.

A few grains of dark angular sand, containing specimens of six common Foraminifera only, brought up in a net lowered to 500 m., hauled to 250 m., then closed. The Lucas Sounding Machine had previously given bottom at 535 m.—rock.

WS 25. TS 586–7. D II.

17. xii. 26. Undine Harbour (North). Small beam trawl, 18–27 m.

Residues and mud from small beam trawl, containing many Foraminifera, *Discorbis globularis* being extremely common and *Cassidulina crassa*, *Ehrenbergina crassa* and *Trochammina malovensis* very common. *Globigerinae* frequent but very pauperate. Most other species very rare.

WS 26. No TS.

18. xii. 26. 53° 33′ 15″ S, 37° 45′ 15″ W. Sounding rod, 1180 m.

A few cc. of slate-grey mud, yielding a residue of Diatoms, Radiolaria and fine sand grains.

WS 27. TS 526. C I.

19. xii. 26. 53° 55′ S, 38° 01′ W. Residue from nets, 106–9 m.

A small quantity of dark muddy sand with organic debris and a few pebbles. Many Foraminifera. *Cassidulina crassa* and *Ehrenbergina crassa* were very common. Many species, but few specimens of *Lagena*.

WS 28. TS 527–8. C I.

19. xii. 26. 53° 48′ 15″ S, 38° 13′ W. Sounding rod, 150–346 m.

Two samples:

(1) About a cubic inch of black sand from net which touched bottom at 145 m. *Haplophragmoides canariensis* very common, other Arenacea frequent, including *Pelosina fusiformis*, *Hippocrepinella*.

(2) From a sounding of 346 m., a small quantity of tenacious grey mud with very few Foraminifera, *Miliammina* only being common.

WS 31. TS 566. E II.

20. xii. 26. 54° 52′ S, 35° 36′ W. Sounding rod, 77 m.

Two stones and a very small quantity of sand. The stones had a few sessile specimens of *Psammosphaera fusca*, *Tolypammina vagans* and *Glomospira gordialis*, and the sand yielded many specimens of shallow-water types representing six species.

WS 32. TS 565 B. E II.

21. xii. 26. Mouth of Drygalski Fjord. Sounding rod, 225 m.

About 25 cc. of light grey mud, which left only 2 cc. on a 200-mesh sieve. Diatoms, fine sand and abundant minute Foraminifera, *Virgulina schreibersiana* dominant, *Textularia tenuissima* common.

WS 33. TS 568 A–B, 569. E II.

21. xii. 26. 54° 59′ S, 35° 24′ W. Sounding rod, 135 m.

(1) *Bottom sample*—about 15 cc. of slate-coloured sandy mud with few Foraminifera. *Ehren-*

bergina crassa was the commonest species. No less than fifteen species of *Lagena*, mostly represented by one or two specimens.

(2) Debris from net which touched bottom at 130 m., sponge and zoophyte fragments, pebbles and black sand with numerous Foraminifera, including *Astrorhiza limicola*, *Planispirina bucculenta* var. *placentiformis*, *Turritellella laevigata*, *Nouria harrisii*, *Hippocrepina indivisa* and other rare forms.

WS 36. No TS.

22. xii. 26. 55° 20′ 15″ S, 34° 46′ 30″ W.

A very small sample of pelagic material from a vertical haul (N 70 V) of 500–250 m. contained many *Globigerinae*; *G. dutertrei* most frequent, then *G. conglomerata*; *G. bulloides* and *G. pachyderma* present, but rare. Specimens rather thin-walled.

Another sample from 250 to 100 m. contained many Copepoda and Diatoms, but few *Globigerinae* of the species *G. dutertrei*, *conglomerata* and *bulloides*.

WS 37. TS 563. E II.

22. xii. 26. 54° 45′ S, 35° 11′ W. Sounding rod, 318 m.

About 15 cc. of tenacious dark grey mud. Very little residue, Diatoms, sponge spicules, angular sand grains. Foraminifera numerous and well developed, but limited in species. Many *Lagenae*.

WS 38. No TS.

22–23. xii. 26. 54° 01′ S, 35° 14′ W.

A very small sample of pelagic material from a vertical haul (N 70 V), 250–100 m., yielded many specimens of *Globigerina dutertrei*.

WS 39. No TS.

22. xii. 26. 54° 08′ S, 35° 43′ W. Sounding rod, 237 m.

About 13 cc. of slate-green mud yielding hardly any residue on a 200-mesh sieve, Diatoms and spicules but no Foraminifera.

WS 40. TS 571. E III.

7. i. 27. 55° 09′ S, 35° 58′ W. Sounding rod, 183 m.

About 12 cc. of dark slate-coloured mud. Residue of pebbles and sand grains of all sizes, Diatoms, a few Radiolaria and Foraminifera, the latter well-developed specimens of the commoner species.

A vertical haul (N 70 V), between 175 and 100 m., yielded a very small sample of pelagic material, principally *Globigerina dutertrei*; *G. bulloides* very rare. All the specimens very thin walled.

WS 41. TS 573. D II.

7. i. 27. 54° 32′ 45″ S, 36° 43′ 45″ W. Sounding rod, 140 m.

About 25 cc. of dark grey mud which yielded very little residue on the 200-mesh sieve, fine sand, Diatoms and many Foraminifera of a few species only, *Virgulina schreibersiana* dominant.

WS 42. TS 574–5. D II.

7. i. 27. 54° 41′ 45″ S, 36° 47′ W. (1) Sounding rod, 175 m.; (2) Net touched bottom, 198 m.

(1) About 15 cc. of tenacious grey mud. Residue of stones, sand, Diatoms and a few Foraminifera.

(2) About 6 cc. of black sand with organic debris. Not many species of Foraminifera but some interesting forms, including *Hippocrepina indivisa* (not found in Sample 1), *Hippocrepinella hirudinea*, and *Textularia tenuissima*. *Ehrenbergina crassa* and other South Georgian species were common in both samples.

WS 43. TS 576. D II.

7–8. i. 27. 54° 54′ S, 36° 50′ W. Sounding rod, 200 m.

About 10 cc. of dark slate-coloured mud, difficult to wash. Residue of sub-angular sand grains, Diatoms and a few Foraminifera of the commoner species.

WS 44. No TS.

8. i. 27. 55° 06′ S, 36° 57′ W.

A small quantity of pelagic material taken in a vertical haul (N 70 V) between 250 and 100 m. yielded abundant *Globigerinae*. *G. dutertrei* was dominant, associated with *G. conglomerata* frequent, and *G. pachyderma* rare. Only a few specimens of *G. bulloides* were present.

WS 45. TS 577. D II.

8. i. 27. 54° 38′ 30″ S, 37° 30′ 55″ W. Sounding rod, 180 m.

About 15 cc. of tenacious dark grey mud. Residue of stones and angular sand grains of all sizes, Diatoms, scanty Foraminifera of common species.

WS 46. TS 578. D II.

8. i. 27. 54° 20′ 15″ S, 37° 32′ 30″ W. Sounding rod, 194 m.

About 12 cc. of slate-coloured mud. Residue of pebbles and sand grains of all sizes, Diatoms, very few Foraminifera, mostly common species, but including a specimen of *Lagena spumosa*.

WS 47. TS 579. D II.

9. i. 27. 54° 22′ S, 37° 50′ W. Sounding rod, 160 m.

About 15 cc. of very tenacious blue-grey mud, yielding 2 cc. of residue, consisting of angular black sand with abundant Diatoms, but very few Foraminifera, which, however, included some interesting forms: *Proteonina tubulata*, *Textularia tenuissima*, and *Cornuspira selseyensis*.

WS 48. TS 580. C II.

9. i. 27. 54° 24′ S, 38° 09′ W. Sounding rod, 224 m.

About 15 cc. of dark slate-coloured mud. Residue of pebbles and angular sand grains, Diatoms, very few Foraminifera of fourteen species only, six of which were *Lagena*.

WS 49. No TS. C II.

9. i. 27. 54° 28′ S, 38° 22′ 15″ W. Sounding rod, 223 m.

About 15 cc. of tenacious dark grey mud. Very little residue, sand grains, spicules, Diatoms. Only a few Foraminifera of the commoner species.

WS 50. TS 581. C II.

9. i. 27. 54° 30′ 30″ S, 38° 40′ 30″ W. Sounding rod, 230 m.

About 10 cc. of tenacious dark slate-coloured mud. Residue principally of a felted mass of Diatoms with many Foraminifera of the usual common species, *Virgulina schreibersiana* dominant.

WS 51. TS 582. C II.

9. i. 27. 54° 34′ S, 38° 57′ W. Sounding rod, 210 m.

A few small sub-angular pebbles and sand grains, many of the pebbles covered with sessile Foraminifera, including a specimen of *Vanhoeffenella gaussi* loosely attached by extruded protoplasm. The few species obtained from the sand included *Miliammina lata* and *Ehrenbergina hystrix* var. *glabra*, suggesting an area rich in species.

WS 52. TS 585. C II.

10. i. 27. 54° 03′ 30″ S, 38° 35′ W. Sounding rod, 84 m.

About 15 cc. of tenacious dark grey mud. Residue of angular black sand, Diatoms, sponge spicules, Radiolaria, and twelve species of Foraminifera, represented by one or two specimens only, except *Miliammina oblonga* and *M. obliqua*, which were frequent.

WS 61. No TS.

18. i. 27. 53° 37′ 30″ S, 37° 06′ 30″ W. Sounding rod, 1893 m.

A few small pebbles, attached to which were four species of sessile Foraminifera. Also some sand grains, many glauconitic, some Radiolaria and Diatoms, but no other species of Foraminifera. The sessile specimens were *Tolypammina vagans* common, *Placopsilina cenomana* many, *Glomospira gordialis* several, and *Psammosphaera fusca* one only.

WS 63. TS 583 A. C II.
20. i. 27. 54° 36′ S, 39° 14′ W. Sounding rod, 1752 m.
About 12 cc. of dark grey mud. Residue of small pebbles and angular sand grains of all sizes, Radiolaria, Diatoms, very few Foraminifera. *Globigerina pachyderma* dominant.

Between WS 63 and 64. TS 583 B. C I, II.
21. i. 27. 54° 36′ S, 39° 14′ W to 53° 48′ 45″ S, 38° 34′ W. Sounding rod, 251 m.
About 12 cc. of dark slate-coloured mud. Residue of a felted mass of Diatoms with a few Foraminifera. *Virgulina schreibersiana* and *Globigerina pachyderma* were extremely common, the few other species rare or very rare.

WS 66. TS 525 E. A I.
18. ii. 27. 53° 31′ 15″ S, 42° 03′ 30″ W. Sounding rod, 150 m.
A very small sample of dark angular mineral grains, broken shells and many Foraminifera, including *Cassidulina laevigata* var. *tumida*, and *Ehrenbergina hystrix* var. *glabra*. Dominant species, *Cassidulina crassa*, *C. subglobosa* and *Globigerina dutertrei*.

WS 110. No TS.
26. v. 27. 53° 46′ S, 35° 47′ W. Sounding rod, about 1000 m.
Three stones with sessile Foraminifera, mostly damaged. There were many specimens of *Tholosina vesicularis* and one each of *Crithionina mamilla* and *Truncatulina lobatula*.

WS 113. TS 543. D II.
28. v. 27. 54° 07′ S, 36° 24′ W. Sounding rod, 155 m.
Three stones coated with tenacious dark blue mud. Residue mainly of Diatoms, the few Foraminifera being pauperate. *Miliammina oblonga*, *M. obliqua* and *Trochammina malovensis* were the only species represented by many specimens. Very fine specimens of *Sorosphaera depressa* on one of the stones.

WS 154. TS 535. D I.
26. ii. 28. 54° 00′ S, 36° 52′ W. Net touched bottom, 160 m.
About two ounces of mud and organic debris, including a large worm tube (?) covered with *Rhizammina algaeformis* and several other sessile species. *Hyperammina subnodosa*, *Vanhoeffenella*, *Hippocrepinella*, *Pelosina*, *Armorella* and *Tholosina* occurred.

WS 177. TS 564. E II.
7. iii. 28. 54° 58′ S, 35° 00′ W. Net touched bottom, 97 m.
A shell, stones, and a worm tube, with a few grains of finer sand, which yielded many species of Foraminifera, suggest that the locality possesses a rich fauna.

WS 314. TS 525 F. B I.
1. xii. 28. 53° 36′ S, 41° 05′ W. Sounding rod, 137 m.
A very small sample; angular mineral grains and shell fragments with abundant Foraminifera, including *Patellina corrugata* and *Polymorphina williamsoni*. Dominant species, *Cassidulina crassa*, *C. subglobosa*, *Globigerina dutertrei*, *G. pachyderma*.

WS 322. No TS. C I.
16. xii. 28. 53° 45′ 30″ S, 38° 23′ W. Sounding rod, 258 m.
A few large sand grains without sessile organisms or Foraminifera.

WS 329. No TS. D I.
27. xii. 28. 53° 56′ 30″ S, 36° 06′ W. Sounding rod, 165 m.
About ½ cc. of dark sand with only a few specimens representing three common species of Foraminifera.

WS 334. TS 552. E I.

30. xii. 28. 53° 19′ S, 35° 10′ 30″ W. Sounding rod, 3705 m.

About 15 cc. of grey ooze with dark specks. Residue of pebbles and angular sand grains of all sizes. Radiolaria, abundant Diatoms and many arenaceous Foraminifera, often fragmentary. *Marsipella cylindrica*, *Proteonina difflugiformis*, *Haplophragmoides subglobosus*, *Psammosphaera fusca* were all frequent. The smaller species were poorly represented but included *Ammochilostoma galeata* and *Textularia nitens*.

WS 336. TS 553. E I.

30. xii. 28. 53° 06′ S, 34° 44′ W. Sounding rod, 3647 m.

About 8 cc. of pale grey mud with darker specks. Residue of pebbles and sand grains of all sizes, Radiolaria and Diatoms. Very few Foraminifera, all arenaceous except *Verneuilina bradyi* and *Clavulina communis*.

WS 340. No TS.

8. i. 29. 53° 32′ S, 37° 12′ 30″ W. Sounding rod, 740 m.

A few sand grains only, the finer material probably washed out on the way up. No organisms.

WS 343. TS 532. D I.

8. i. 29. 53° 02′ S, 37° 06′ W. Sounding rod, 2856 m.

About 17 cc. of greenish grey mud which left only 2 cc. on the 200-mesh silk sieve. Residue of Diatoms, Radiolaria and fine angular sand. Foraminifera very starved, and extremely rare, only six species being recorded, among which were *Textularia tenuissima* and *T. nitens*.

WS 344. No TS.

9. i. 29. 52° 50′ S, 37° 01′ W. Sounding rod, 2215 m.

A few tiny pebbles, one of which bore a specimen of *Tolypammina vagans*, the only organism seen.

WS 345. No TS.

9. i. 29. 52° 41′ S, 37° 06′ W. Sounding rod, 2174 m.

A single tiny pebble without sessile organisms.

WS 348. TS 558. E II.

11. i. 29. 54° 23′ 10″ S, 35° 52′ W. Sounding rod, 135 m.

About 55 cc. of tenacious slate-coloured mud. Residue largely of Diatoms, sponge spicules and fine sand. Very few Foraminifera, all of common types.

WS 349. TS 559. E II.

11. i. 29. 54° 23′ S, 35° 32′ 30″ W. Sounding rod, 267 m.

About 35 cc. of fine grey mud with hardly any coarse residue, fine sand, Diatoms, spicules, Radiolaria. Not many Foraminifera, all very small and pauperate. *Virgulina schreibersiana* and *Globigerina pachyderma* common.

WS 351. TS 561. E II.

11. i. 29. 54° 21′ 30″ S, 34° 59′ W. Sounding rod, 1170 m.

About 15 cc. of blue-grey mud. Residue of pebbles and sand grains of all sizes, Diatoms, Radiolaria and very few Foraminifera. These included *Cyclammina cancellata*, *Marsipella elongata*, *Proteonina tubulata*, *Lagena fimbriata* and *Bolivina cincta*, six species of *Globigerina* and three of *Globorotalia*.

WS 353. TS 562. E II.

12. i. 29. 54° 18′ S, 34° 25′ W. Sounding rod, 4041 m.

About 25 cc. of light grey ooze. Residue consisting of a flocculent mass of Diatoms, Radiolaria and angular sand grains in about equal proportions. Very few Foraminifera and, except for a few large fragmentary Arenacea, all were small and pauperate. No Globigerinidae or Rotaliidae.

WS 357. TS 567. E II.

13. i. 29. 54° 55′ 30″ S, 35° 30′ W. Sounding rod, 264 m.

About 25 cc. of dark blue mud. Residue of pebbles, sub-angular sand grains of varying sizes, Diatoms, spicules, and a very few Foraminifera, *Uvigerina angulosa* dominant.

WS 361. No TS. E III.

14. i. 29. 55° 24′ S, 34° 42′ W. Sounding rod, 1444 m.

About 0·5 cc. of coarse sand, with three sessile arenaceous species attached to the larger grains, and a few specimens of *Globigerina pachyderma* among the finer portion.

WS 363. No TS. E III.

14. i. 29. 55° 38′ S, 34° 14′ W. Sounding rod, 1332 m.

A small pebble and a little sand. *Tolypammina vagans* and *Tholosina vesicularis* sessile on the pebble; no other organisms.

WS 365. TS 570. F III.

14. i. 29. 55° 52′ 10″ S, 33° 53′ W. Sounding rod, 3219 m.

About 20 cc. of light grey mud containing pebbles and sand grains, many Radiolaria and Diatoms but very few Foraminifera. Only six species were identified in all.

WS 373. TS 556. E II.

22. i. 29. From 54° 10′ S, 35° 40′ W to 54° 27′ S, 34° 58′ W. Sounding rod, 1540 m.

About 4 cc. of yellowish grey mud with dark specks. Residue of angular sand grains of all sizes, Radiolaria, Diatoms and very few Foraminifera.

WS 418. TS 572. D III.

10. iv. 29. 55° 02′ 30″ S, 36° 31′ W. Sounding rod, 227 m.

About 2 cc. of dark sandy mud. Residue of pebbles and sand grains with scanty Foraminifera. *Uvigerina angulosa* and *Globigerina pachyderma* dominant, *Miliammina* curiously rare.

WS 425. No TS. C II.

15. iv. 29. 54° 37′ 10″ S, 39° 07′ 30″ W. Sounding rod, 228 m.

One small black pebble without sessile organisms.

WS 426. TS 584. C II.

15. iv. 29. 54° 38′ 35″ S, 39° 22′ W. 1500–2000 m.

Some pebbles and a few grains of coarse sand obtained from a reversing water-bottle, which touched bottom between these depths. Many sessile Foraminifera on the pebbles and seven species obtained from the sand, including *Cyclammina cancellata*, *Ammodiscus incertus* and *Glomospira gordialis*, suggest a rich local fauna. A bottom-sample of pebbles only from 2433 m. furnished the same sessile species.

WS 428. TS 525 D. A I.

29. iv. 29. 53° 07′ S, 42° 30′ W. Sounding rod, 1966 m.

A very small quantity of dark grey sand, with much glauconite, some Radiolaria, Diatoms and a few Foraminifera. *Globigerina dutertrei* was the only species occurring with any frequency.

WS 429. TS 525 B.[1]

30. iv. 29. 53° 02′ 30″ S, 45° 28′ W (between South Georgia and the Falkland Islands). Sounding rod, 2549 m.

Fine grey mud yielding a residue of Radiolaria, Diatoms, fine angular mineral grains and many Foraminifera, including *Proteonina tubulata*, *Reophax spiculifer*, *Textularia nitens*, and many species of *Lagena*. Dominant species, *Globigerina pachyderma*, *G. dutertrei*, *Globorotalia crassa*, *Nonionella iridea*.

WS 521. TS 525 A.

28. ii. 30. 52° 41′ S, 49° 14′ W (between South Georgia and the Falkland Islands). Sounding rod, 3780 m.

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[1] This Station (and the next three) are outside the range of West Longitude of Fig. 1.

Light grey mud yielding a residue of mineral grains of all sizes, *Globigerina* ooze and Radiolaria in about equal proportions. *Globigerinae* of several species dominant. Many interesting and rare species including *Bolivina cincta*, *B. decussata*, *Ehrenbergina bradyi*, *Lagena formosa*.

WS 522. TS 525 G.

28. ii. 30. 52° 56′ S, 47° 14′ W (between South Georgia and the Falkland Islands). Sounding rod, 2550 m.

Light grey *Globigerina* ooze with angular pebbles, sand grains and glauconite. *Globigerina* and *Globorotalia* of various species formed quite 98 per cent of the organic remains. A long list of other Foraminifera mostly represented by single specimens, including many *Lagenae*.

WS 523. TS 525 C.

2. iii. 30. 53° 07′ S, 45° 00′ W (between South Georgia and the Falkland Islands). Sounding rod, 1697 m.

Grey mud, yielding a residue of Radiolaria, Diatoms and fine mineral grains with a few Foraminifera, including *Hormosina globulifera*, *Reophax spiculifer* and *R. robustus*. *Globigerina pachyderma* dominant, forming the bulk of the organic residue.

No station no. TS 565 A. E II.

21. xii. 26. Drygalski Fjord (to NW of Station WS 32). Sounding rod, 178 m.

About 1 cc. of tenacious blue mud and a pebble. Residue of sand grains and mud pellets with ten species of Foraminifera. *Pelosina rotundata*, *P. variabilis* were common, *Miliammina* frequent, *Spiroplectammina biformis* and *Textularia tenuissima* very rare.

STATIONS MADE BY THE STAFF OF THE MARINE BIOLOGICAL STATION

MS 14. TS 605. (See Fig. 2.)

17. ii. 25. From 1·5 miles SE × S to 1·5 miles S ½° W, of Sappho Point, East Cumberland Bay. Small dredge 109–180 m.

A small quantity of coarse black angular sand with organic debris (residues from small dredge), yielded many species of Foraminifera, mostly rare, except *Miliammina oblonga* and *Ehrenbergina crassa*, which were common.

MS 68. TS 606–8. (See Fig. 2.)

2. iii. 26. 1·7 miles S ½° E to 8½ cables SE × E of Sappho Point, East Cumberland Bay. Rectangular net 220–247 m.

Several gatherings of mud, sand and sponge debris from nets, yielded a large number of species, including many rarities, in spite of the unsatisfactory nature of the material, which was very hard to clean. The area would appear to be very rich in Foraminifera if sufficient material could be collected. *Hippocrepinella hirudinea*, *H. alba*, *Hippocrepina oviformis*, *Textularia tenuissima*, *Miliammina lata*, etc.

LIST OF NEW GENERA, SPECIES AND VARIETIES

Flintia soluta
**Gordiospira*, gen.n.
**Gordiospira fragilis*
Astrorhiza triangularis
Vanhoeffenella oculus
Pelosina fusiformis
Pelosina variabilis var.n. *constricta*
Storthosphaera elongata var.n. *impudica*
**Sorosphaera depressa*
**Pelosphaera*, gen.n.
**Pelosphaera cornuta*
Proteonina decorata
Webbinella limosa
**Armorella*, gen.n.
**Armorella sphaerica*
Thurammina protea
**Hippocrepinella*, gen.n.
**Hippocrepinella hirudinea*

*_Hippocrepinella hirudinea_ var.n. _crassa_
*_Hippocrepinella alba_
Reophax subfusiformis
Reophax distans var.n. _gracilis_
Ammobaculites bargmanni
*_Ammobaculites rostratus_
Turritellella laevigata
*_Miliammina_, gen.n.
*_Miliammina cribrosa_ nom.n. (p. 90)
*_Miliammina lata_
*_Miliammina obliqua_
*_Miliammina oblonga_
Textularia nitens
Textularia tenuissima nom.n.
Textularia wiesneri
Bigenerina minutissima
*_Ehrenbergina crassa_
Lagena formosa var.n. _costata_
Lagena hartiana
Lagena herdmani
Lagena mackintoshiana
Discorbis margaritaceus

* These genera and species were figured and described by E. Heron-Allen and A. Earland in the _Journal of the Royal Microscopical Society_ in 1929–32. The descriptions and plates are repeated in this Report by the courtesy of the Council of the Society.

SYSTEMATIC ACCOUNT

Note. To economize space, no synonyms are given for species which have already been described in the Report on the Falkland area. For purposes of reference, the Falkland No. is printed in brackets after the specific name: e.g. _Biloculina murrhyna_, Schwager (F 3).

Order FORAMINIFERA

Family MILIOLIDAE

Sub-family _MILIOLININAE_

Genus **Biloculina**, d'Orbigny, 1826

Note. The _Biloculinae_ have been determined from external characters only, as time has not allowed for the preparation of sections. The genus is difficult to diagnose with certainty, owing to the lack of superficial distinctions.

1. **Biloculina murrhyna**, Schwager (F 3).

Three stations: WS 429, 521, 522.

Rare everywhere and the specimens are small and pauperate, the best being at WS 522. All the stations are in deep water, between 2000 and 4000 m.

2. **Biloculina serrata**, Bailey (F 4).

One station: WS 523.

A single weak and broken specimen. The serration is confined to the aboral edge.

3. **Biloculina bradyi**, Schlumberger.

Biloculina ringens, Brady, 1884, FC, p. 142, pl. ii, fig. 7.
Biloculina bradyi, Schlumberger, 1891, BGF, p. 557 (in the reprints p. 170), text-figs. 15–19, pl. x, figs. 63–71.

Five stations: 27, 45, 126; WS 154, 177.

Common at several of the stations; the best specimens at WS 154 and WS 177.

4. **Biloculina vespertilio**, Schlumberger (F 10^A).

Five stations: 27, 45, 123, 144, 148.

Confined to the Cumberland Bay area, where it is frequent and attains large dimensions, notably at St. 45.

5. **Biloculina milne-edwardsi**, Schlumberger.

Biloculina milne-edwardsi, Schlumberger, 1891, BGF, p. 567 (in the reprints p. 180), text-figs. 29, 30, pl. xi, figs. 79, 80.

Five stations: 27, 45, 126, 144, 148.

This species appears to be almost confined to the Cumberland Bay area, where it is common and attains large dimensions, particularly at Sts. 45 and 144.

6. **Biloculina elongata**, d'Orbigny (F 6).

Twelve stations: 27, 30, 45, 123, 126, 144, 148, 149; WS 33, 42, 113; MS 14.

Never very common. Most frequent at St. 144, where the specimens were of a small regular type, very like our British form. This small form is the usual type, but the species attains a large size at some stations, notably Sts. 144 and 148. Occasional large specimens are found at stations where the small type prevails. From St. 144 a large specimen was received preserved in spirit, with a branching mass of protoplasm and mud, extending from the orifice in lobose processes, its bulk largely exceeding that of the test. Protoplasmic masses, extracted from spirit specimens obtained at this station and stained, were found to be loaded with Diatoms taken in as food, but there was no mud in this internal protoplasm.

7. **Biloculina patagonica**, d'Orbigny (F 7).

Four stations: 27, 126, 140, 144.

Very rare always, the best specimens at St. 126.

8. **Biloculina anomala**, Schlumberger (F 10).

Five stations: 27, 45, 149; WS 25, 33.

A few specimens appear to be referable to this species, so far as external characteristics are concerned, but Schlumberger himself admits the difficulty of identification. They are always uncommon.

9. **Biloculina pisum**, Schlumberger.

Biloculina pisum, Schlumberger, 1891, BGF, p. 569 (in the reprints p. 182), text-fig. 31, pl. xi, figs. 81–3.

Nine stations: 27, 123, 126, 140, 144; WS 66, 177, 314, 522.

Not very common, except at WS 177, where many excellent and typical specimens were obtained. Larger, but less typical, and rare at Sts. 126, 144.

10. **Biloculina globulus**, Bornemann (F 11).

Three stations: 27; WS 27, 33.

Very rare, mostly single specimens.

Genus **Flintia**, Schubert, 1911

11. **Flintia soluta**, sp.n. (Plate I, figs. 1–4).

Two stations: 27, 144.

Test large, porcellanous, smooth and highly polished; the last two chambers are extremely inflated and separated by a space within which the ante-penultimate chamber is exposed to a variable extent. Aperture large, with slightly recurved lip, furnished with a broad incurved tooth having rounded extremities. Length up to 2·0 mm. In the best specimen, the greatest width of the final chamber was 0·64 mm., of the penultimate chamber 0·9 mm., while the width of the median space or ante-penultimate chamber was only 0·24 mm.

Very rare, a single specimen at St. 144, several at St. 27. No attempt has been made to cut sections owing to paucity of material, but the internal structure is doubtless regularly biloculine, the separation being confined to the final chambers.

This is apparently the most rudimentary form of the genus, and its approximation to *Biloculina* is so close that the specimens were at first regarded as mere abnormalities, there being considerable differences in the extent of exposure of the earlier chambers, even among the few specimens which have been found. The extremely inflated contour shows some resemblance to *Biloculina isabelleana*, d'Orbigny (F 9), but the aperture is very different. In this feature, and in the curvature of the edge of the chambers, there is a close resemblance to *Biloculina peruviana*, d'Orbigny (F 8), from which it is probably derived.

Genus **Miliolina**, Williamson, 1858

12. **Miliolina seminulum** (Linné) (F 12).

Ten stations: 27, 123, 149, 660; WS 27, 28, 43, 177, 314, 522.

Singularly rare, seldom more than one or two specimens at each station.

13. **Miliolina vulgaris** (d'Orbigny) (F 14).

Four stations: 27, 45; WS 27, 66.

A single large specimen at each station, except at WS 66, where the example is very small.

14. **Miliolina oblonga** (Montagu) (F 15).

Four stations: 45, 144, 149; WS 27.

Not uncommon at the three Discovery stations, where it is represented by a small thin-shelled form. At WS 27, it is represented by a single large and normal specimen.

15. **Miliolina bosciana** (d'Orbigny) (F 16).

Four stations: 140, 144, 149; WS 33.

Rare and very small at WS 33. More frequent at the other stations. All the specimens are very thin-walled.

16. **Miliolina subrotunda** (Montagu) (F 18).

Six stations: 45, 144, 145, 157; WS 25, 27.

Typical but very rare, except at WS 25, where it is fairly frequent.

17. **Miliolina lamarckiana** (d'Orbigny) (F 20).

One station: WS 50.

A single small specimen.

18. **Miliolina pygmaea** (Reuss) (F 25).

Three stations: 149; WS 32, 33.

Very rare, the best specimens at WS 32; very small and pauperate at St. 149.

19. **Miliolina venusta** (Karrer) (F 26).

One station: WS 25.

A single small specimen.

20. **Miliolina tricarinata** (d'Orbigny) (F 28) (Fig. 3).

Eight stations: 45, 144, 148; WS 33, 43, 429, 522, 523.

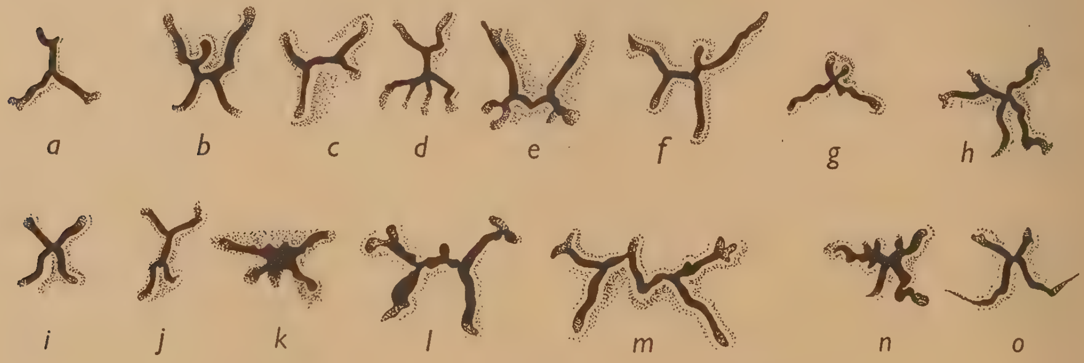

Fig. 3. Variations in the aperture of *Miliolina tricarinata*.

Usually rare and very small at WS 429, 522. Larger at WS 33. At St. 144 the species is common and attains a very large size up to 2·0 mm. in length. The aperture at this station varies with the size of the individual, being typically Milioline in the smallest, cruciform in the medium, and irregularly stellate in the largest specimens. The medium specimens are identical with the figure of *Cruciloculina triangularis*, d'Orbigny, recorded by him from the Falkland area, but which was not discovered in the Falkland material. The accompanying figure illustrates some of the range of variation in the aperture.

Wiesner has recorded as a new variety, *M. tricarinata* var. *crucioralis* (W. 1931, FDSE, p. 105) what is apparently a typical *Cruciloculina triangularis*, d'Orbigny. Wiesner does not figure his specimens, but the description is of an identical organism.

21. **Miliolina circularis** (Bornemann) (F 29).

Six stations: 123, 126, 144, 145; WS 27, 28.

Except at WS 27, where small specimens are common, the species is very rare. Seldom more than a single specimen, which is often a large one, at each station. Very large at Sts. 126 and 144.

Genus **Sigmoilina**, Schlumberger, 1887

22. **Sigmoilina obesa**, Heron-Allen and Earland (F 38).

One station: WS 27.

A single specimen only.

23. **Sigmoilina tenuis** (Czjzek) (F 40).

Four stations: WS 334, 353, 429, 521.

Very rare everywhere, but exhibiting the same range of convexity as in the Falkland area.

Sub-family *HAUERININAE*

Genus **Tubinella**, Rhumbler, 1906

24. **Tubinella funalis** (Brady) (F 41).

Six stations: 30, 123, 149; WS 25, 27, 33.

Rare everywhere, but large and typical specimens at Sts. 123, 149, WS 27. Wiesner (FDSE, 1931, pp. 67, 109, pl. i, fig. 6; pl. xv, fig. 183; pl. xvi, figs. 184–5) has made this species the type of a new genus *Tubinellina*, on the grounds of a suspected relationship with *Tubinella perforata*, Rhumbler (FLC, 1906, p. 27, pl. ii, fig. 5). But the similarity appears to be external only. Rhumbler's species is distinctly perforate, and if really a foraminifer, would be widely separated from *T. funalis*, which exhibits no sign of perforation of the wall. Rhumbler would appear to have assigned his specimen to *Tubinella*, akin to *Articulina*, largely because he supposed the specimen figured by Millett under the name *Articulina funalis* var. *inornata* (Millett, 1898, etc., FM, 1898, p. 513, pl. xii, fig. 11) to indicate signs of perforation. Millett's type specimens are in the H.-A. and E. collection and I have subjected them to an examination under a high power. Their nature appears to be rather uncertain, but they are not perforate. The markings shown in Millett's drawing are foreign bodies, some being food particles.

Genus **Planispirina**, Seguenza, 1880

25. **Planispirina irregularis** (d'Orbigny) (F 43).

Seven stations: 140, 144; WS 27, 33, 154, 177, 314.

A good series in all stages of growth at St. 140, and WS 33 and 154, and single excellent specimens at the other stations.

26. **Planispirina sphaera** (d'Orbigny) (F 44).

Three stations: 27, 144, 148.

Many large and typical specimens at St. 144, single good individuals at the other stations.

27. **Planispirina bucculenta** (Brady) (F 45).

Two stations: 27, 144.

A single large specimen at St. 27. Many in all stages of growth at St. 144.

28. **Planispirina bucculenta var. placentiformis** (Brady).

Miliolina bucculenta var. *placentiformis*, Brady, 1884, FC, p. 171, pl. iv, figs. 1, 2.
Planispirina bucculenta var. *placentiformis*, Chapman, 1914, EDRS, p. 43, pl. v, fig. 5.

One station: WS 33.

Many specimens in all stages of growth.

Sub-family *PENEROPLIDINAE*

Genus **Cornuspira**, Schultze, 1854

29. **Cornuspira involvens** (Reuss) (F 46).

Nine stations: 30, 123, 144, 149; WS 25, 27, 33, 113, 348.

Always rare or very rare except at St. 144, where it was frequent in both megalospheric and microspheric forms, and St. 149, where the microspheric form was frequent and larger than the average, the South Georgian specimens being usually small. The megalospheric form is as usual predominant.

30. **Cornuspira selseyensis**, Heron-Allen and Earland (F 48).

Seven stations: 27, 45, 123, 144, 145, 149; WS 47.

Always very rare, but good specimens especially at Sts. 45, 144 and WS 47.

31. **Cornuspira foliacea** (Philippi) (F 50).

Five stations: 45, 144, 148, 149; MS 68.

Always very rare but good specimens, notably at St. 144, where a perfect individual over 3 mm. in diameter was found. Fragments of specimens almost as large were seen at MS 68.

32. **Cornuspira diffusa**, Heron-Allen and Earland (Plate I, figs. 5–7).

Cornuspira foliacea, Brady, 1884, FC, pl. xi, fig. 7 (monstrous specimen, no ref. in text).
Cornuspira foliacea, Rhumbler, 1903, ZRR, p. 287, fig. 141 *b*.
Cornuspira diffusa, Heron-Allen and Earland, 1912, etc., NSG, 1913, pp. 272–6, pl. xii; CI, 1913, p. 37; FWS, 1916, p. 217.
Cornuspirella diffusa, Cushman, 1918, etc., FAO, 1929, p. 85, pl. xxi, figs. 6, 7.

Two stations: 149; MS 68.

Many characteristic fragments at each station.

Genus **Gordiospira**, Heron-Allen and Earland, 1932.

Test free, porcellanous, very thin-walled and fragile, approximately circular in shape, consisting of a proloculum around which a non-septate tubular chamber forms several coils in different planes, finally becoming planospiral, and involute for several convolutions. In the planospiral stage the tube rapidly expands in width and thickness. The umbilical area is depressed and exhibits the edges of some of the earliest convolutions. Aperture large and terminal.

Gordiospira is isomorphous with *Glomospira*, Rzehak (1885), but the irregular convolutions of the initial coil are less visible externally. They become very evident in transparent preparations.

33. **Gordiospira fragilis**, Heron-Allen and Earland (Plate VI, figs. 10–15).

Gordiospira fragilis, Heron-Allen and Earland, 1929, etc., FSA, 1932, p. 254, pl. i, figs. 1–6.

Six stations: 45, 144, 145, 149; WS 33; MS 68.

Test free, porcellanous, oval when young, becoming circular with full growth, very thin and fragile, papery white or translucent, surface often irregular and marked with recurved lines of growth. Viewed as an opaque object, it exhibits 2–3 planospiral and embracing whorls of a tube, which increases in diameter and thickness so rapidly that the final convolution forms the bulk of the entire test. The central portion of the test is depressed, and shows one or two transverse tubes. The aperture is terminal, very large, the outer margin projecting, the inner margins recurved to join the previous whorl.

Viewed as a transparent object, *Gordiospira fragilis* is seen to consist of a proloculum around which an unseptate tube is irregularly coiled in 3–5 convolutions set in different planes. Subsequently, the tube becomes planospiral, forming 2–3 convolutions rapidly increasing in size and thickness. These later convolutions are involute to some extent, each concealing at least half of the previous convolution.

The surface of the tubes is often rather irregular and always exhibits faint recurved lines of growth.

Both megalospheric and microspheric forms have been identified, the latter being the larger, as usual. The megalospheric proloculum is about 0·02 mm. in diameter, the microspheric too small to be measured with certainty. The size of the test ranges up to 1·5 mm. or rather more, in diameter, but the general average is under 1·0 mm.

Small specimens are usually oval in contour, owing to the change in shape when the tube assumes the planospiral condition. After the first planospiral convolution, it rapidly assumes a more circular contour.

Specimens taken direct from spirit, stained and mounted in balsam show that the protoplasmic body is voluminous, almost filling the tube from end to end. The protoplasm is finely granular and filled with food bodies, including Diatoms and spicules.

Gordiospira fragilis was observed at six stations in South Georgia, and is frequent at Sts. 45, 149, MS 68, at all of which a series in all stages was obtained. In depth its range extends between 26 and 270 m.

Family ASTRORHIZIDAE

Sub-family *ASTRORHIZINAE*

Genus **Astrorhiza**, Sandahl, 1857

34. **Astrorhiza limicola**, Sandahl (Plate I, fig. 32).

Astrorhiza limicola, Sandahl, 1857, *Öfvers. K. Vet. Ak. Forh.*, XIV, p. 299, pl. iii, figs. 5, 6.
Astrorhiza limicola, Brady, 1884, FC, p. 231, pl. xix, figs. 1–4.

Three stations: 27, 144; WS 33.

The rarity of this species in what might have been regarded as favourable surroundings is rather surprising. A single specimen only was found at each station, and every example is small compared with the individuals dredged off our own coasts. The specimen from WS 33 is noteworthy as incorporating many long sponge spicules in its material. These spicules project irregularly, and their presence is probably quite fortuitous, though they may serve as supports in the ooze. I do not recall having previously seen spicules so used in this genus.

35. **Astrorhiza crassatina**, Brady.

Astrorhiza crassatina, Brady, 1879, etc., RFC, 1881, p. 47; 1884, FC, p. 233, pl. xx, figs. 1–9.
Astrorhiza crassatina, Goës, 1894, ASF, p. 13, pl. ii, figs. 11–15.
Astrorhiza crassatina, Flint, 1899, RFA, p. 265, pl. ii.

One station: 45.

A single recognizable fragment.

36. **Astrorhiza triangularis**, sp.n. (Plate I, figs. 8, 9).

Two stations: 144, 148.

Test triangular, compressed and cushion-shaped, consisting of a thin shell of sand grains of varying sizes firmly cemented together and enclosing the single chamber, which occupies the whole interior of the test. An aperture at each corner, flush or provided with a short external tube. Surface rough, owing to the projecting sand grains. Average length of side, excluding oral tubes, about 1·3 mm. Tube up to 0·3 mm. in length.

Very rare at the two stations at which it was observed, but eight specimens in all were found.

It differs from *A. angulosa*, Brady, in the character of the interior chamber, which is large and occupies the whole body of the test, the apertures opening directly into it. In Brady's species, the walls, built of fine sand only, are very thick and the central chamber is not much more than a junction, formed by the three tubes diverging to the orifices at the angular points.

Genus **Iridia**, Heron-Allen and Earland, 1914

37. **Iridia diaphana**, Heron-Allen and Earland (F 52).

Two stations: 30; WS 25.

Several very good specimens were found at WS 25, and a single, less typical, at St. 30.

Genus **Vanhoeffenella**, Rhumbler, 1905

38. **Vanhoeffenella gaussi**, Rhumbler (Plate I, figs. 16–21).

Vanhoeffenella gaussi, Rhumbler, 1905, MF, p. 105, fig. 9; 1909, FPE, p. 216, fig. 57.
Vanhoeffenella gaussii, Heron-Allen and Earland, 1922, TN, p. 76, pl. i, figs. 14, 15.

Nine stations: 27, 45, 126, 140, 144, 148; WS 51, 154, 334.

Frequent at Sts. 27, 140, 144, 148, rare or very rare elsewhere.

Vanhoeffenella has hitherto been known only from Rhumbler's original description; our own note on two specimens found in the Terra Nova material (exact locality unknown), and recently from a record by Wiesner (W 1931, FDSE, p. 78, pl. iii, figs. 21–6) whose specimens came from the Antarctic, near the coast of Kaiser Wilhelm Land, depth 70–385 m. Its occurrence, in considerable numbers, in some of the South Georgian material greatly enlarges our knowledge of the genus, and enables me to correct the observations made on the Terra Nova specimens. We then described "the angular framework supporting the characteristic chitinous membrane which forms the two faces of *Vanhoeffenella*" as "a hollow tube with labyrinthic interior, constructed of minute Diatom and mineral débris".

The present examination of a long series of specimens proves that this tubular appearance is only assumed by collapsed and pauperate individuals, and that the structure is really much more simple.

Vanhoeffenella may be compared to a tambourine, the parchment sides of which are represented by the two chitinous faces. These are separated, and in life kept widely apart, by the rim, which is a flat belt of chitin agglutinated with mud, fine sand and Diatoms. At intervals this belt widens out and forms tubular extensions. These vary in number from one or two in the smallest individuals to as many as six or seven in large specimens. They are formed by the extension of one of the chitinous faces together with one edge of the sandy belt. The chitin forms the greater part of one side of the tube, the sandy rim folding over on itself to complete the other side, and the end. The tubes are formed from either edge of the belt; the sandy side of a tube may be either uppermost or underneath, as the individual lies on one chitinous face. Most specimens show tubes formed from either edge. The development of the first few tubes in many specimens exhibits great regularity, the tubes being spaced evenly round the rim. This regularity seldom persists beyond the formation of the third tube, specimens with five to seven tubes often having them very irregularly disposed.

After death there is a tendency for the chitinous sides of the tambourine to collapse and come together, with the result that the flat sandy belt folds inwards and forms an encircling tube.

The earliest stage of *Vanhoeffenella* observed is oval with a tube at each extremity. The smallest specimen seen measured only 0·45 mm. in greatest diameter, including the tubes. It was sessile on a pebble at WS 51, attached by protoplasm extending from the two tubes. Development proceeds at first by an expansion of one side of the oval from which a third tube is extended, and later by constant enlargement of the rim with the formation of additional tubes. The greatest diameter of the adult ranges between 1·0 and 2·0 mm. (including tubes). Average diameter about 1·0 mm.

Specimens apparently multiplying by fission have been found. In one case this proceeds by contraction of the specimen, the rims being pinched in towards each other. In another much larger specimen, a sandy rim has commenced to grow across the chitinous membrane.

Vanhoeffenella is not a mud-feeder. The protoplasmic body is large and opaque but not loaded with mud and Diatoms like many of its relatives.

The distribution of the type round South Georgia is confined to shallow water, 100–270 m. There is one remarkable exception which appears to be distinct.

39. **Vanhoeffenella oculus**, sp.n. (Plate I, fig. 22).

One station: WS 334.

A single specimen found at this station at the abnormal depth of 3705 m. presents differences which appear to be worthy of specific distinction. In form the test is an almost perfect oval and the tubular extensions, two in number, are small, purely chitinous and of the frailest kind. They might easily be entirely overlooked. The specimen is presumably a dead individual, as there is no trace of protoplasm within the central diaphragms, and the sandy rim which is constructed of the finest material has collapsed to form a tube. Similar specimens occur in deep water in the Antarctic area.

Greatest width 0·6 mm., least width 0·5 mm., exclusive of the rudimentary tubes.

Genus **Pelosina**, Brady, 1879

40. **Pelosina rotundata**, Brady.

Pelosina rotundata, Brady, 1879, etc., RRC, 1879, p. 31, pl. iii, figs. 4, 5; 1884, FC, p. 236, pl. xxv, figs. 18–20.
Pelosina rotundata, Cushman, 1918, etc., FAO, 1918, p. 55, pl. xxi, figs. 4–6.

Ten stations: 27, 30, 140, 143, 144, 148; WS 25, 154; Drygalski Fjord; MS 68.

Frequent to common at nearly all stations and quite typical, the test being constructed of mud. At MS 68 many of the specimens, though otherwise perfect, were flattened or collapsed, apparently owing to the thinness of the mud wall.

41. **Pelosina fusiformis**, sp.n. (Plate I, figs. 10–12).

Seven stations: 45, 126, 144, 148, 149; WS 28, 154.

Test free, fusiform, one end usually more prolonged than the other and provided with an extended but usually collapsed neck. Wall, firm and thick, and composed of mud with or without admixture of sand grains, smooth and neatly finished. Internal cavity rather small, the two walls accounting for more than half the maximum diameter of the test. The inner wall of the cavity generally exhibits a number of funnel-shaped depressions through which no doubt the protoplasm extrudes, although they do not extend to the outer surface of the test. The cavity usually contains a sub-spherical solid mass, which is the protoplasmic body containing a food mass of Diatoms enclosed in the chitinous lining of the test. Colour grey.

Length up to 2·0 mm. breadth up to 1·2 mm.

Very common at Sts. 45, 148, frequent elsewhere. There is considerable variation in the amount of sand incorporated; at WS 28 a good deal of black sand is used, whereas at St. 45 none at all. The aperture is seldom visible except in the few instances where the protruding neck has resisted disintegration.

P. fusiformis does not occur in company with *P. rotundata* except at Sts. 144, 148 and WS 154. Fusiform specimens of *Pelosina rotundata* have been recorded by Egger and Millett (E. 1893, FG, p. 254, pl. xi, fig. 60; M. 1898, etc., FM, 1899, p. 249, pl. iv, figs. 1 *a*, *b*), and although their figures are not identical with the South Georgian specimens, it is probable that they represent the same organism, which I regard as specifically separable from *P. rotundata*.

42. **Pelosina variabilis**, Brady.

Pelosina variabilis, Brady, 1879, etc., RRC, 1879, p. 30, pl. iii, figs. 1–3; 1884, FC, p. 235, pl. xxvi, figs. 7–9.
Pelosina variabilis, Flint, 1899, RFA, p. 266, pl. iv, fig. 1.

Thirteen stations: 27, 28, 45, 140, 143, 144, 148, 149; WS 27, 47, 154; Drygalski Fjord; MS 68.

Frequent to common at most of the stations where it was recorded, although perfect specimens are not very frequent. It often attains a large size, notably at Sts. 27, 45 and 148. At several stations the specimens are very narrow and elongate and the walls are more smoothly finished than usual. Such specimens are evidently closely allied to others which I am separating under the varietal name *constricta*. They are found at Sts. 28, 143, 144 and 149, sometimes in company with the normal type.

43. **Pelosina variabilis** var. **constricta**, var.n. (Plate I, figs. 13–15).

Five stations: 45, 126, 140, 144; MS 68.

Test long, narrow, tapering to each extremity, broadest near the oral aperture which is usually furnished with a short, distinct tube. More or less constricted at irregular intervals, as many as five constrictions have been observed. There is no evidence that the constriction indicates septation, but it probably marks a stage of growth. The test is constructed of very fine mud, neatly finished and devoid of larger incorporated particles.

Length up to 6·0 mm.; breadth up to (about) 0·80 mm.

Frequent at MS 68, rare at the other stations, the best specimens at St. 45. In the Antarctic gatherings it reaches far greater dimensions than in material from South Georgia. Specimens have been found measuring up to 4 cm. in length.

Genus **Storthosphaera**, F. E. Schulze, 1875

44. **Storthosphaera elongata**, Cushman.

Storthosphaera elongata, Cushman, 1918 etc., FAO, 1918, p. 40, pl. xviii, figs. 1, 2; pl. xix, fig. 1.

Two stations: 45, 144.

At St. 144 a single specimen, agreeing exactly with Cushman's description and figure, and with British specimens from West Scotland, 205–1600 m., and South-west Ireland, 523–680 fathoms, where it is not uncommon. Cushman's types were from the North Atlantic region about 40° 16′ N, 67° W.

At St. 45 a form is common, which I think is probably only a local form of *S. elongata*. It is smaller, rarely more than half the usual dimensions, and very variable in shape, ranging between sub-spherical, compressed, and cylindro-elongate, sometimes four times as long as wide. The character of the test agrees with Cushman's description: "wall comparatively thin, composed of a felted mass of fine amorphous material and a large percentage of acerose sponge spicules with little or no cement; aperture not developed, surface smooth, colour greyish-white".

It would be difficult to separate the sub-spherical and compressed varieties from *Crithionina*, but for the thin test and large central cavity, facts to which Cushman has drawn attention. Nor would it seem possible to assign these varieties to the same species as the very elongate forms but for the presence of a complete series of connecting links.

45. **Storthosphaera elongata var. impudica**, var.n. (Plate I, figs. 23, 24).

Two stations: 45, 144.

In general construction the test agrees with the type, the wall being thin and the cavity large and entire. But at about half its length the test is sharply constricted and continues growth in cylindrical form of about half the previous width. The entire organism has a grotesque *phallus* shape.

Length up to 2·4 mm. Breadth 1·2 mm. at broader, 0·7 mm. at narrower, extremity.

Genus **Crithionina**, Goës, 1894

46. **Crithionina granum**, Goës (F 54).

Two stations: 144; WS 33.

Frequent but poorly developed at WS 33, large but rare at St. 144.

47. **Crithionina mamilla**, Goës (F 55).

Two stations: 144; WS 110.

A single specimen, sessile on *Hyperammina subnodosa* at St. 144, and another on a stone at WS 110, are the only certain records. A few doubtful specimens were seen elsewhere, not worth recording.

48. **Crithionina pisum**, Goës (F 56).

Four stations: 144; WS 27, 33; MS 14.

Singularly rare. The only specimens recorded without hesitation as belonging to this species were from St. 144, where several good examples were obtained. Spicules are largely employed, with the usual fine sand, and it is not easy to state when the specimens should be attributed to the type, and when to var. *hispida*. Two specimens from this station which are otherwise typical are transfixed by very long spicules, which no doubt serve the same purpose as the similar variation in *Psammosphaera parva*, viz. to support the organism in the surface film of ooze. At the other stations the specimens are small and obscure.

49. **Crithionina pisum var. hispida**, Flint.

Technitella melo de Folin (*non* Norman), 1895, SRR, p. 13, pl. O, fig. 3.
Crithionina pisum var. *hispida*, Flint, 1899, RFA, p. 267, pl. vi, fig. 2.
Crithionina abyssorum, Kiaer, 1899, NNAE, p. 7, pl. i, figs. 1–4.
Crithionina pisum var. *hispida*, Heron-Allen and Earland, 1909, TNS, p. 410, pl. xxxiv, fig. 7.

Two stations: 144; WS 27.

Good specimens are frequent at WS 27, less typical at St. 144.

Genus **Dendronina**, Heron-Allen and Earland, 1922

50. **Dendronina papillata** (Heron-Allen and Earland) (F 59).

One station: 126.

Two specimens in the youngest or "basal pad" stage.

Sub-family *PILULININAE*

Genus **Bathysiphon**, M. Sars, 1872

51. **Bathysiphon capillare**, de Folin (Plate I, fig. 26).

Bathysiphon capillare, de Folin, 1887, B, p. 276, pl. v, fig. 2 *a–e*; 1887, RR, p. 114, fig. 7 *b*.

Eight stations: 27, 45, 140, 144, 148; WS 33; Drygalski Fjord; MS 14.

Fragments are not uncommon at most of the stations and very common at WS 33, but there is only one approximately perfect specimen, at St. 45. This is regularly tapering and curved and the apertural end rounded off, with a central opening. Total length 3·4 mm. Maximum width 0·14 mm. The texture of the tube varies considerably, in some specimens fine sand grains are liberally used, in others only fine mud. The wall is unpolished, thin and frequently collapsed.

The specimens are attributed with some hesitation to *B. capillare*, as they appear to agree better with de Folin's figure and description than with any other species. At the same time there appears to be little difference between this species and *B. filiformis* except size, and the duller surface of the tube.

52. **Bathysiphon rufescens**, Cushman (Plate I, fig. 25).

Bathysiphon rufescens, Cushman, 1917, NFP, p. 651; 1921, FP, p. 43, pl. ii, fig. 3.

Three stations: 30, 45; MS 14.

Fragments only, the best at St. 45. In spite of their small size, the largest fragment being only 2·15 mm. in length, they appear to agree generally with Cushman's species, which attains a length of 15 mm. in deep water off the Philippines.

Cushman describes his species as very slightly curved or tapering, slender, the wall marked by annular rings, surface rough, very light yellowish or reddish brown, dull, differing from *B. rufum* in the rough granular surface and straight test.

The South Georgian specimens have these characters. They are rusty brown in colour.

53. **Bathysiphon rufum**, de Folin.

Bathysiphon rufum, de Folin, 1887, B, p. 283, pl. vi, figs. 8 *a–c*.
Bathysiphon rufus, Cushman, 1918, etc., FAO, 1918, p. 29; 1921, FP, p. 42, pl. ii, fig. 2.

Two stations: 53° 00′ S, 34° 22′ W; WS 336.

A single specimen at each station. That from WS 336 is a small curved individual regularly tapering to a point and marked by many superficial constrictions. At the other station only a fragment of a large specimen was found. Both are of a yellowish colour, in which feature they would agree better with *B. flavidum*, de Folin; but that species is stated to be sub-cylindrical and only very slightly tapering. There is, however, considerable range in the colour of *B. rufum* within our experience, and so I assign the South Georgian specimens to that species. There appears to be some likelihood that de Folin's two species are really identical, his figure of *B. flavidum* does not suggest a perfect specimen.

Sub-family *SACCAMMININAE*

Genus **Sorosphaera**, Brady, 1879

54. **Sorosphaera confusa**, Brady.

Sorosphaera confusa, Brady, 1879, etc., RRC, 1879, p. 28, pl. iv, figs. 18, 19; 1884, FC, p. 251, pl. xviii, figs. 9, 10.
Sorosphaera confusa, Rhumbler, 1903, ZRR, p. 235, fig. 63.
Sorosphaera confusa, Cushman, 1918, etc., FAO, 1918, p. 39, pl. xv, figs. 4, 5.

Three stations: 144; WS 33, 154.

Extremely rare. One excellent free specimen at St. 144 and a good sessile one at WS 154. A very doubtful specimen at WS 33.

55. **Sorosphaera depressa**, Heron-Allen and Earland (Plate V, figs. 20, 21).

Sorosphaera depressa, Heron-Allen and Earland, 1929, etc., FSA, 1929, p. 102, pl. i, figs. 1, 2.

Eight stations: 17, 27, 136, 144, 148; WS 33, 113, 365.

Test attached, light to dark grey in colour according to the constituent particles, consisting of a variable number of irregularly shaped chambers spreading without definite plan over a stone or other surface of attachment, and often following a crack or superficial depression for protection. The walls are thin, firmly and smoothly constructed of fine sand grains and cement, but they are dull and unpolished. The outer surface is rougher than the interior wall of the chambers, which have a chitinous lining.

Each chamber forms a distinct and separate entity enclosed within its own walls and base. There is no sign of any aperture or means of communication between the chambers. Communication with the external medium can be only through minute interstitial openings in the wall of the test. The openings shown in Plate V, fig. 21, are only incidental fractures of the wall.

When a colony is attached to a stone, as in Plate V, fig. 21, the test forms quite a solid object capable of sustaining considerable stress, but when growing on a flexible base, the chambers are readily separable without fracture of the walls of the test (see Plate V, fig. 20).

Monothalamous Arenacea, when sessile, are usually more or less semi-globular in plan, but in *Sorosphaera depressa* the chambers are distinctly polygonal. This in some cases is due to the irregularities of the surface of attachment, but specimens have been observed (see Plate V, fig. 20) which suggest that the organisms first form a quadrate colony, and thereafter spread irregularly in the line of greatest protection or least resistance.

The dimensions of the chambers vary considerably from 0·3 to 0·8 mm. in diameter. A colony may cover a space of 0·5 square centimetre. The thickness of the wall is only about 0·02 mm.

Always very rare, but some good specimens at St. 27 and WS 113, where it was more frequent than at any other station. Both sessile and free individuals were found, the latter always showing evidence in their flat base of having become detached.

Genus **Psammosphaera**, F. E. Schulze, 1875

56. **Psammosphaera fusca**, Schulze (F 60).

Thirty-five stations: 17, 30, 42, 123, 126, 140, 144, 148, 151; 53° 00′ S, 34° 22′ W; WS 27, 28, 31, 32, 33, 40, 42, 51, 61, 63, 154, 334, 336, 348, 349, 351, 353, 365, 373, 429, 521, 522, 523; Drygalski Fjord; MS 68.

Generally distributed and sometimes frequent, notably at WS 32 and 154. Exceptionally large single specimens up to 3·0 mm. in diameter were found at St. 151, WS 63 and 521 in company with normal individuals. There is the usual wide range of variation, but the general average for the area is a rather small and neatly constructed form. At those stations where the bottom deposit contains black sand, e.g. St. 148, WS 28 and

154, it has a rather striking appearance owing to the contrast of the black sand with the copious grey cement used for building purposes. At St. 140 and WS 33 spicules were utilized as well as sand grains, a rather unusual occurrence, those at the latter station being left projecting, perhaps to act as supports, though their irregular disposition does not show much evidence of selection.

57. **Psammosphaera parva** (Flint).

Psammosphaera fusca, de Folin, 1895, SRR, p. 16, pl. O, figs. 4, 5.
Psammosphaera parva, Flint, 1899, RFA, p. 268, pl. ix, fig. 1.
Psammosphaera parva, Heron-Allen and Earland, 1912, etc., NSG, 1913, p. 17, pl. ii, figs. 7, 8.
Psammosphaera parva, Cushman, 1919, RFNZ, p. 594, pl. lxxv, fig. 3.

Eight stations: 20, 28, 29, 42, 144, 149; WS 33, 46.

Rare or very rare at all the stations and seldom as neatly constructed as usual. Only a single specimen of the selective form, which is transfixed by a sponge spicule, was found at St. 144.

58. **Psammosphaera rustica**, Heron-Allen and Earland (Plate I, fig. 27).

Psammosphaera rustica, Heron-Allen and Earland, 1912, etc., NSG, 1912, p. 383, pl. v, figs. 3, 4; pl. vi, figs. 2–4.
Psammosphaera rustica, Cushman, 1918, etc., FAO, p. 37, pl. ix, figs. 3, 4; pl. x, figs. 2–4.

One station: 144.

A single large specimen. It is not so highly selective as the types from the North Sea, the body of the test being constructed of fine sand and cement, but it possesses the characteristic projecting spicules.

Genus **Pelosphaera**, Heron-Allen and Earland, 1932

Test large, free, roughly spherical, constructed of large and small irregularly shaped mineral grains joined firmly together with copious cement, which externally is soft and friable, but internally firm and smooth. Furnished externally with two or more projecting processes, conical in shape, hollow, formed of fine sand grains and loosely aggregated mud and cement, similar in appearance to the external cement between the sand grains of the test. There is no visible external aperture to either the test or the processes, but the processes extend from, and conceal, large apertures in the test, which are clearly seen from the inside, when the sphere is laid open.

This is a very distinctive form in the perfect condition, but the conical processes are so friable that few specimens retain them throughout the cleaning process. Devoid of processes, the specimens, except for their abnormal size, would pass for *Psammosphaera fusca*, the apertures being usually concealed by mud. Only a few young individuals were found. These bear two processes only, sometimes almost equalling in length the diameter of the sphere, and usually, but not always, built of smaller sand grains than those employed by the adult organism.

Pelosphaera is no doubt closely allied to *Psammosphaera*, but even without its typical processes would be distinguishable by its relatively enormous size and the friable nature of the external cement.

59. **Pelosphaera cornuta**, Heron-Allen and Earland (Plate VII, figs. 24–7).

Pelosphaera cornuta, Heron-Allen and Earland, 1929, etc., FSA, 1932, p. 255, pl. ii, figs. 12–15.

Five stations: 17, 27, 126, 144, 148.

The characteristic features of the genotype have been given under the description of the genus. The best specimens, both large and small, were obtained at Sts. 126, 144 and 148, where the material was obtained from nets attached to the trawl, and the specimens had been subjected to less friction than at St. 27. At this station, dredged material had been passed through sieves with the result that few specimens retained the characteristic processes. It is of frequent occurrence at Sts. 27, 126 and 148—rare elsewhere. At St. 17 the only specimen found is abnormal, both in size and shape. It is roughly triangular in outline, about 6·0 mm. in greatest diameter, and constructed of relatively enormous sand grains. A specimen from St. 148, which was laid open, contained a large, orange-coloured sphere almost filling the central cavity, which is probably the protoplasmic body in a chitinous envelope. Similar enclosures have been found in *Pelosina*. Dimensions range between 3·0 and 5·0 mm. in diameter.

Genus **Saccammina**, M. Sars, 1868

60. **Saccammina sphaerica**, M. Sars.

Saccammina sphaerica, M. Sars, 1868, LUHD, p. 248.
Saccammina sphaerica, Brady, 1884, FC, p. 253, pl. xviii, figs. 11–17.
Saccammina sphaerica, Heron-Allen and Earland, 1912, etc., NSG, 1913, p. 1, pl. i and pl. ii, figs. 1, 2.

One station: 151.

A single rather small specimen.

61. **Saccammina minuta**, Rhumbler.

Saccammina minuta, Rhumbler, 1909, etc., FPE, 1913, p. 375, pl. i, figs. 8, 9.

Two stations: WS 343, 349.

Very rare, never more than one or two specimens at a station.

Genus **Proteonina**, Williamson, 1858

62. **Proteonina difflugiformis** (Brady) (F 61).

Twenty stations: 13, 30, 42, 131, 136, 144, 151; 53° 00′ S, 34° 22′ W; WS 33, 42, 48, 334, 336, 343, 349, 353, 428, 429, 522, 523.

Frequent at WS 429, but rare or very rare elsewhere. Considerable variation in construction is exhibited by specimens from different stations, but the most common form is a long oval flask of quartz grains showing no attempt at neatness of construction, the exterior being rough and irregular. Such specimens are usually small, but at St. 42, WS 353, 428 and 523 they are very much larger than average size. The last three stations are in deep water between 1697 and 4041 m. A neatly constructed variety, in which the sand grains are laid so as to form a smooth exterior, occurs in company with the rough form at Sts. 144 and 151, and by itself at WS 33 and 349. At the former station, the sand grains in two of the three specimens are too small to be distinguishable. A very abnormal specimen was noted at WS 522, nearly globular and ferruginous, with a large slightly projecting oral extremity. It may possibly be a proloculum of *Reophax nodulosus*, but this species was not recorded at the station.

63. **Proteonina decorata**, sp.n. (Plate I, figs. 28, 29).

Three stations: WS 28, 32, 41.

Test free, monothalamous, pyriform or fusiform, devoid of a produced neck; the aperture, which is small, being situated at the narrower extremity of the test. Wall rather thick, rough externally and internally, constructed of large irregular sand grains, embedded in very fine sand and cement, the cement predominating, so that the sand grains appear to be scattered over the surface like plums in a cake. Length 0·6 mm., breadth 0·30 mm.

This is rather a striking form in appearance, owing to the marked contrast between the dark sand grains and the white cement which forms the bulk of the test.

It is rare at all the stations, the best specimens at WS 28.

64. **Proteonina tubulata** (Rhumbler) (Plate I, figs. 30, 31).

Saccammina tubulata, Rhumbler, n.sp., Wiesner, 1931, FDSE, p. 82, pl. xxiii, Stereo-fig. *a*.

Six stations: 45, 136; WS 47, 351, 353, 429.

Test more or less globular and roughly constructed of comparatively large mineral grains embedded in cement. Exterior rough owing to the projecting edges of the sand grains. Aperture furnished with a projecting neck built of very minute sand grains neatly cemented together. Owing to its fragility the neck is seldom, if ever, perfect, but at WS 351 its length is about three-quarters that of the body of the test.

Length of test without neck 0·3–0·4 mm., breadth about the same; length of neck up to 0·2 mm., width 0·02 mm.

This is a very distinctive form owing to the contrast between the roughly finished shell and the delicately constructed neck. Though very rare, seldom more than a single specimen at a station, its distribution is sufficiently wide to justify specific distinction. In depth it ranges between 160 and 2549 m. It has recently been described and figured by Wiesner (*ut supra*) from two stations of the German South Polar Expedition, depths 385 m. and 3410 m. under what is apparently a MS. name of Rhumbler's. I cannot agree with Rhumbler's attribution of the species to *Saccammina*. The long neck, in itself, seems to forbid such an association.

Genus **Webbinella**, Rhumbler, 1903

65. **Webbinella depressa**, Heron-Allen and Earland (F 64).

Two stations: 27, 145.

A single specimen only at St. 27 and two excellent specimens at St. 145.

66. **Webbinella limosa**, sp.n. (Plate II, figs. 1, 2).

Two stations: 27, 126.

Test sessile, monothalamous, irregular in form but usually roughly circular, more or less highly convex. Wall rather thick and without visible aperture, composed of mud and very fine sand grains. Friable but sufficiently firm to allow the convex test to be detached as a whole from its surface of attachment. The test is then seen to consist of a single irregularly shaped cavity with thin basal floor. The cavity is nearly always filled with a mass of Diatoms and mud ingested as food. Colour yellowish grey.

Size from 1·0 to 2·0 mm. in diameter.

Not uncommon at the two stations where it occurs sessile on small pebbles. Most of the specimens have been more or less damaged in the cleaning process, the convex shape and friable wall causing it to be easily worn away.

W. limosa is no doubt closely allied to *W. depressa*, Heron-Allen and Earland, but is readily distinguishable owing to its greater convexity, thicker but more friable wall and yellowish colour.

Genus **Tholosina**, Rhumbler, 1895

67. **Tholosina bulla** (Brady) (F 65).

Seventeen stations: 27, 45, 123, 140, 144, 145, 148, 149; WS 27, 33, 40, 42, 154, 334, 353; MS 14, 68.

Less abundant than *T. vesicularis* but common at Sts. 27, 144 and 149 and very common at WS 33. Mostly rare elsewhere. There is considerable range of variation in the convexity of the test: very highly convex specimens at St. 149 and MS 68. At Sts. 45 and 123 small specimens attached to sponge spicules and zoophyte stems are almost globular in shape. They appear to be very similar to Wiesner's figures of *Tholosina laevis*, Rhumbler (W. 1931, FDSE, p. 86, pl. vii, figs. 80–2). If they are identical there seems little excuse for the formation of a new species.

The material employed varies at different stations, at some only fine sand is used, at others coarse sand, the latter being distinguishable from *T. vesicularis* only by the absence of the apertural tubes.

68. **Tholosina protea**, Heron-Allen and Earland (F 66).

Six stations: 27, 144, 145; WS 25, 27, 154.

Detached specimens only were observed, except at St. 145. They are frequent, both large and small, at the three WS stations, rare at the others. Nearly all the various eccentric shapes observed in the Falkland material occur, but many of the specimens appear to have been attached to sponge spicules, judging by the shape of the scar of attachment.

69. **Tholosina vesicularis** (Brady) (F 67).

Eighteen stations: 17, 20, 27, 31, 126, 136, 144, 148, 149; 53° 00′ S, 34° 22′ W; WS 33, 40, 42, 51, 110, 154, 363, 418.

Very common indeed at St. 144 and common at Sts. 27, 126, 148, WS 33 and 110, frequent to rare at the remaining stations. The specimens, with few exceptions, are quite typical. At St. 144, in addition to the type, specimens were seen sessile on sponge spicules, the two apertural tubes being extended along the spicule in each direction. At St. 27 a single specimen had long collapsed chitinous tubes extending freely from the ends of the usual attached tubes.

70. **Tholosina vesicularis** var. **erecta**, Heron-Allen and Earland (F 68).

Recorded with hesitation, no perfect specimen having been seen. Fragmentary tubes, which may belong to this variety, were noticed at Sts. 30, 129, WS 25 and 33.

Genus **Armorella**,[1] Heron-Allen and Earland, 1932

Test free, monothalamous, approximately spherical, furnished with a variable number of extended tubes of different length, with an aperture at the end of each tube. Wall firm, but very thin, constructed of fine sand, Diatoms and sponge spicules incorporated with much cement, occasional larger sand grains and spicules projecting from the otherwise smooth and rather shining surface. Interior surface similarly smooth. Colour light grey.

This is a very distinctive form, closely allied to *Thurammina* and *Tholosina*, its affinities probably lying with the latter genus. Small specimens furnished with short tubes, or remains of broken tubes, are very like *Thurammina papillata* in their spherical form, but a series of specimens links them up with the large and multitubular individuals, which have no resemblance to that species. Moreover the broken tube ends are very unlike the aperture of *Thurammina*.

Small sponge spicules are often employed to a considerable extent as building material, being smoothly incorporated in the wall. In specimens from St. 144, they play a larger part than usual in construction, the sphere in some cases being built round a bundle of spicules, the ends of which may project to an extent equal to the diameter of the test. This spicular construction to some extent also modifies the shape of the test, which tends to become polyhedral instead of spherical. Such tests are probably not evidence of selective powers, or only in a limited degree comparable with the use of spicules in *Psammosphaera rustica*. But these projecting spicules would undoubtedly serve a useful purpose in supporting the organism in the surface layer of mud, and this would be of value to the animal, which is not one of the mud-eaters. The protoplasmic body is large, but not loaded with mud and Diatoms as in many Arenacea.

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[1] In memory of Armorel Daphne Heron-Allen, who died July 3, 1930, aged 22.

On the other hand, a specimen found at St. 45 exhibits a definite instance of selection, similar to *Psammosphaera parva*, the spherical test, which is very neatly built of fine sand only, being transfixed by a very long spicule (Fig. 21).

These projecting spicules are sometimes used as supports for the tubes which are attached to them. But there is no general practice, and frequently a tube is seen growing out quite close to a projecting spicule, but unattached.

Armorella has probably a wide distribution in deep or cold waters. A similar organism, though specifically distinct, has been found in several dredgings round the British Isles, but always of rare occurrence. Several of the figures attributed to *Thurammina* in Haeusler's papers would appear to be referable to our genus, in which case its record extends back to Jurassic times.

71. **Armorella sphaerica**, Heron-Allen and Earland (Plate VII, figs. 16–23).

Armorella sphaerica, Heron-Allen and Earland, 1929, etc., FSA, 1932, p. 257, pl. ii, figs. 4–11.

Twelve stations: 27, 31, 45, 123, 140, 144, 148, 149; WS 33, 154, 334; MS 68.

The description of the genus is sufficient for the species, which is very common at St. 144, common at Sts. 148, 149, frequent at Sts. 45 and 140, very rare at the remaining stations. The range of depth lies between 110 and 270 m., except for a single specimen at WS 334 in 3705 m. There is a considerable range of size, the specimens reaching 1·2 mm. in diameter without tubes. An average size is about 1·0 mm. in diameter. Tubes average up to 0·3 mm. in length. There can be no doubt that the small individuals, which represent the species at those stations where it is rare, are merely young or pauperate individuals.

The external texture of the test varies to a lesser extent. In general the sphere is smooth externally, owing to its homogeneous construction, but occasionally the animal incorporates sand grains which, being larger than the thickness of the wall, project and give an unfinished appearance to the test.

The tubes vary enormously both in size and number. It is difficult to give a maximum, as a broken tube may leave little trace. Specimens with four tubes are common. The length of the tube has no relation to the size of the sphere: many large specimens have very short tubes and *vice versa*.

Genus **Thurammina**, Brady, 1879

In 1917 we published a paper "On *Thurammina papillata*, Brady; a Study in Variation" (H.-A. and E. 1912, etc., NSG, No. 5, 1917) in which we expressed the opinion that "all hitherto recorded species of the genus *Thurammina*, including *Thuramminopsis canaliculata*, Haeusler, are referable to a single specific type, *Thurammina papillata*, Brady", and that while "for taxonomical reasons numerous varietal names must be employed...they have no biological significance".

The experience of the intervening years has not caused me to vary from the opinion then expressed. On the contrary, I believe that a similar intensive study of other genera will in time result in an enormous reduction of so-called species. Nevertheless in a report of this character it seems more convenient to minimize the number of varietal names employed, and I am therefore reverting to the use of specific names instead of the varietal names used in our paper.

72. **Thurammina papillata**, Brady.

Thurammina papillata, Brady, 1879, etc., RRC, 1879, p. 45, pl. v, figs. 4–8; 1884, FC, p. 321, pl. xxxvi, figs. 7–8.
Thurammina papillata, Heron-Allen and Earland, 1912, etc., NSG, 1917, p. 543, pl. xxvi, figs. 1–13; pl. xxvii, figs. 9–13.

Two stations: 123; WS 33.

The typical sandy sphere is almost absent from our material. Apart from a small individual at St. 123, the only specimen which can be referred to the type is a chitinous individual characterized by an abnormal number of papillae, which are scattered as closely as possible all over the partially collapsed sphere. A sponge spicule transfixes one side of the sphere.

73. **Thurammina haeusleri** (Heron-Allen and Earland).

Thurammina papillata, Haeusler, 1883, JVT, pp. 262–6, pl. viii, figs. 5–8, 11, 13–24; 1890, FST, pp. 46 *et seq.*, pl. vi, figs. 14, 18.
Thurammina papillata, Brady, 1884, FC, p. 321, pl. xxxvi, figs. 13, 14 (only).
Thurammina papillata var. *haeusleri*, Heron-Allen and Earland, 1912, etc., NSG, 1917, p. 547, pl. xxviii, figs. 1–12; pl. xxix, fig. 16; pl. xxx, fig. 8.

Three stations: 27, 123, 144.

Rare everywhere, most numerous at St. 123 where the specimens were small. A single large individual at Sts. 27 and 144.

74. **Thurammina parallela** (Heron-Allen and Earland).

Thurammina papillata var. *parallela*, Heron-Allen and Earland, 1912, etc., NSG, 1917, p. 546, pl. xxvii, figs. 14–17.

One station: 144.

Only two specimens were observed, one of which was very small, the other large and typical. Occasionally *T. protea* takes on this habit, but never attains such length as to justify separation from its type, the length of the specimens seldom exceeding twice the breadth.

75. **Thurammina albicans**, Brady.

Thurammina albicans, Brady, 1879, etc., RRC, 1879, p. 46; 1884, FC, p. 323, pl. xxxvii, figs. 2–7.
Thurammina papillata var. *albicans*, Heron-Allen and Earland, 1912, etc., NSG, 1917, p. 550, pl. xxix, figs. 12–15.

One station: WS 365.

A single specimen from 3219 m. at this station.

76. **Thurammina protea**, sp.n. (Plate II, figs. 3–10).

Nine stations: 20, 27, 123, 140, 144, 148; WS 154, 348; MS 14.

Test free or sessile, typically monothalamous but sometimes forming an aggregation of two or more individuals, without direct communication with each other beyond the apertures in the wall, which is thin but firm, constructed of fine sand and ferruginous cement on a chitinous membrane. Apertures in the form of small nipple-like protuberances, very variable in number and prominence, either scattered over the wall of the test or more frequently confined to salient edges. Shape protean, cushion-like or hemispherical when sessile, but when free irregular, angular and polyhedral. Colour rusty brown. Size very variable, ranging up to 1·6 mm. in diameter. Average 1·0 mm.

Although not generally distributed *T. protea* is one of the most striking and characteristic of the South Georgian Foraminifera and by far the most abundant representative of its genus, all the other species being comparatively rare. It is common at St. 27 and WS 154, frequent to rare at the other stations.

It is more frequently found in the sessile condition than any other form of *Thurammina*, and in this condition appears to be closely related to *T. hemisphaerica*, Haeusler (H. 1883, ALB, p. 60, pl. iv, figs. 14, 14 *a*; and H. 1890, FST, p. 47, pl. vii, figs. 10, 11). Young specimens in the sessile condition are circular and cushion-shaped, almost devoid of nipples, or having them only round the margin. Later the specimens become irregular in outline and form, and develop nipples over the surface.

There is no doubt that the extraordinary shapes assumed by the organism are largely due to the conditions under which it lives, either attached to other bodies, or in crevices. In many cases it takes up its abode inside the empty tubes of *Hyperammina subnodosa*, and probably inside other tube-forming organisms. This leads to the formation of a cylindrical test, examples of which were found at St. 144 (*in situ* in *H. subnodosa*) and WS 154. The specimen from the latter station is an aggregate of three individuals in line.

The shape of the species is particularly protean at WS 154, the irregularity being due to the formation of the test in the crevices of other organisms, or between pebbles. The specimens have taken the exact impress of the cavity, and the apertures are confined to the exposed marginal edge, the remainder of the test being quite smooth.

At St. 27 a very curious specimen was found which had grown around two large tetractinellid sponge spicules, possibly while the spicules were still projecting from the sponge. Another instance of incorporated spicules was observed at WS 348, but such inclusions, whether of spicules or large sand grains, are very rare.

T. protea is evidently closely related to *T. haeusleri*, but appears to be quite a distinctive local form.

77. **Thurammina tuberosa**, Haeusler.

Thurammina tuberosa, Haeusler, 1890, FST, p. 49, pl. vi, fig. 24; pl. vii, figs. 6–9.
Thurammina papillata var. *tuberosa*, Heron-Allen and Earland, 1912, etc., NSG, 1917, p. 548, pl. xxviii, figs. 13–16.

Three stations: 123, 144, 148.

Frequent at St. 144, where the best specimens were found. Very rare at the remaining stations. The specimens are not highly complex aggregations, such as were figured by Haeusler, but simpler aggregations such as we figured, especially in pl. xxviii, fig. 13 (*ut supra*).

Sub-family *RHABDAMMININAE*

Genus **Jaculella**, Brady, 1879

78. **Jaculella obtusa**, Brady (F 70) (Plate II, fig. 11).

Four stations: 16; WS 40, 353, 429.

Very rare, only single specimens at each station and those very small. The specimen from WS 40 is rather interesting, being built almost entirely of broken sponge spicules, selected of approximately proportionate length according to their position in the tube. They are cemented together at right angles to the axis of the specimen and so give a quadrate shape to the oral end. Length 1·6 mm.

Genus **Hippocrepina**, Parker, 1870

79. **Hippocrepina indivisa**, Parker (Plate IV, figs. 31–4).

Hippocrepina indivisa, Parker, 1870, GSTL, p. 176, fig. 2.
Hippocrepina indivisa, Brady, 1881, HNPE, p. 100, pl. ii, figs. 3, 4; 1884, FC, p. 325, pl. xxvi, figs. 10–14.

Five stations: 144; WS 33, 40, 42, 154.

Single specimens at St. 144, WS 40, 154, five at WS 33 and eight at WS 42, which is the deepest station, in 198 m. All the specimens are fine and typical except one at WS 42, in which the aperture is large, occupying nearly the whole of the oral extremity, and surrounded by an irregular reverted collar. It is probable that such specimens represent an individual in the act of enlarging its test, the apertural end being absorbed prior to the addition of fresh material lengthening the test. It may be remarked that all Brady's figures are drawn from specimens in this condition.

80. **Hippocrepina oviformis**, Heron-Allen and Earland.

Hippocrepina oviformis, Heron-Allen and Earland, 1914, etc., FKA, 1915, p. 617, pl. xlvi, figs. 23, 24.

One station: MS 68.

A single specimen, which agrees with the original figure of the type from the Kerimba Archipelago, East Africa. The type specimen is unfortunately not available for comparison, damp having caused deterioration.

81. **Hippocrepina flexibilis** (Wiesner) (Plate II, figs. 12–15).

Technitella flexibilis, Wiesner, 1931, FDSE, p. 85, pl. vii, fig. 75.

Four stations: 144, 149; WS 28, 32.

Test monothalamous, pear-shaped with a well-defined aperture at the narrow end, aboral end rounded. Wall thin, very smooth but unpolished, constructed of very minute particles without visible cement. Colour light grey. Size about 0·5 mm. long, 0·25 mm. broad.

Frequent at WS 28 and 32, very rare at the other stations. The shape of this little organism agrees with that of *Proteonina difflugiformis*, but the character of the test is quite distinctive and indicative of relationship to *Hippocrepina oviformis*, Heron-Allen and Earland. In life, the test is probably flexible, several of our specimens being collapsed without fracture. There can be little doubt that the South Georgia specimens are identical with *Technitella flexibilis*, Wiesner. He describes his species as snow-white, oval, very flexible when wet but collapsing when dried. The dry shell is said to be rigid and comparatively strong, built of the finest possible mineral fragments. The aperture is small and circular on a produced neck. Wiesner's figures agree with the South Georgian specimens, but I do not agree with his attribution of the species to *Technitella*, the shell structure being quite different and showing no selective tendency.

Genus **Hippocrepinella**, Heron-Allen and Earland, 1932

Test free, monothalamous, irregularly cylindrical and sometimes curved, furnished with two terminal apertures. Wall thin compared with the size of the large central cavity, constructed of extremely fine sand and mud with little cement, and generally without inclusion of larger particles; smoothly and neatly finished, but often exhibiting numerous fine transverse wrinkles. It is probably flexible during life, but dry specimens are rigid and fragile. Colour varying from white to very dark grey.

Although widely distributed round the coast-line of South Georgia, *Hippocrepinella* is mainly characteristic of the Cumberland Bay area, the majority of the records being from stations in or near that bay. It favours the tenacious mud found in that area, although a few specimens have been recorded elsewhere on sandy bottoms.

Hippocrepinella appears to be closely related to *Hippocrepina*. Indeed, but for the existence of the secondary aperture, we should have had no hesitation in referring the specimens to that genus, as the wall of the test is very similar in character though more delicate. Also, owing to the finer materials employed in its construction, the surface of the test is smoother and more polished.

Of the two apertures, one, which may be regarded as the principal oral opening, is always well defined and sometimes quite large, while the secondary or basal opening is usually inconspicuous, and sometimes only to be detected with difficulty.

There is little doubt that the test is flexible and extensible in life. The apertural ends probably expand for the absorption of food and contract for digestion, opening again for the rejection of the empty Diatom shells, which form the food of the animal. Diatom valves have been observed inside the cavity, of dimensions larger than the aperture. The flexibility of the living test would also account for the curvature of some specimens and the transverse wrinkles observed in others.

82. **Hippocrepinella hirudinea**, Heron-Allen and Earland (Plate VII, figs. 1–9).

Hippocrepinella hirudinea, Heron-Allen and Earland, 1929, etc., FSA, 1932, p. 258, pl. i, figs. 7–15.

Thirteen stations: 27, 28, 45, 123, 126, 140, 143, 144, 148, 149; WS 28, 42; MS 68.

Test free, monothalamous, irregularly cylindrical, occasionally curved, rounded at the extremities which are sometimes slightly clavate, sometimes tapered off. Wall thin, smooth and neatly finished, shining or "matt", often covered with fine transverse wrinkles. Apertures, central and terminal, usually varying in size, one being more pronounced than the other. Colour varying from light to dark grey. Size up to 2·0 mm. in length, 0·5 mm. in width.

This species, which is the genotype, is very variable in size and general appearance, while very constant in its specific features. Although many specimens are to be found in perfect condition, the majority exhibit compression, distortion or shrinkage in varying degrees. The explanation is to be found in the condition of the interior of the test. We, ourselves, have laid open many tests, and Mr J. T. Holder, F.R.M.S., has been so good as to cut serial longitudinal sections of others. The cavity is found to be more or less compactly filled with an ingested mass of food-stuffs, principally Diatoms (Figs. 2–3), and it depends upon the compactness of this mass, whether or not the test preserves its outline after death. Mr Holder's sections have also been useful, in demonstrating the fineness of the material used in construction, and the almost total absence of larger particles of sand.

Occasional specimens noticed at several stations, notably Sts. 140 and 144, exhibit a number of irregularly placed pustular openings in the walls of the test, the origin of which is obscure. From the nature of the openings, they are clearly not due to external agencies, but originate inside the test. They may be subsidiary openings for the emission of young individuals, but it seems more probable that they are made by minute organisms, perhaps Nemertine worms, which have been ingested with the mud-mass as food, and have successfully eaten their way through the wall of their captor.

Hippocrepinella hirudinea is very common at St. 45, common at Sts. 144 and 148, all three of which are in or off Cumberland Bay. At the other stations it is rare or very rare. In depth the range extends between 100 and 346 m.

An abnormal specimen found at St. 45 is bifurcate at one extremity, each of the arms bearing the usual aperture (Plate VII, fig. 1).

83. **Hippocrepinella hirudinea** var. **crassa**, Heron-Allen and Earland (Plate VII, figs. 13–15).

Hippocrepinella hirudinea var. *crassa*, Heron-Allen and Earland, 1929, etc., FSA, 1932, p. 259, pl. ii, figs. 1–3.

Two stations: 660; WS 32.

General characteristics as in the species, but the test is much broader in proportion to its length, of an elongate oval or fusiform shape, round in section or compressed.

Walls thicker and composed of coarser material, rough in texture, apertures inconspicuous. Length 1·2 mm., breadth 0·5 mm.

The genotype *Hippocrepinella hirudinea* was not recorded at either St. 660 or WS 32. Its place appears to be taken by a form which we prefer to regard as a variety, rather than as a separate species, although its appearance is very distinctive, especially in the case of the specimens from St. 660, which is in Cumberland Bay. The specimens from WS 32 are less rough. The organism is rare at both stations.

84. **Hippocrepinella alba**, Heron-Allen and Earland (Plate VII, figs. 10–12).

Hippocrepinella alba, Heron-Allen and Earland, 1929, etc., FSA, 1932, p. 259, pl. i, figs. 16–18.

Seven stations: 27, 45, 126, 144; WS 33, 154; MS 68.

Test monothalamous, cylindrical or fusiform, furnished with a large principal aperture on a produced neck, with or without a collar; a secondary basal aperture may be present; wall very smooth and of paper-like thinness, constructed of very minute particles without visible cement. Inner cavity enormous compared with the thickness of the wall. Colour uniformly dead white.

Size very variable, the largest specimen being 0·30 mm. broad and 2·80 mm. long, and the smallest 0·52 mm. long and 0·09 mm. broad.

The above account is an attempt to describe an organism which, owing to its rarity and fragility, is represented by very few entire specimens, hardly any of which agree in all details, though all conform in the nature of the test.

The wall of the test is extremely thin in comparison with the size of the organism, and, owing to the absence of cement and the uniformly minute size of the particles employed in its construction (apparently fragmentary Diatoms), is, when dry, fragile to the last degree. In life it is almost certainly flexible and distensible, but nearly all our specimens are more or less collapsed and broken.

The great variation of specimens in size probably represents stages of growth only, although there is an equally remarkable range of form between broadly fusiform and elongate cylindrical.

The most striking point of difference in the specimens lies in the form of the aboral extremity. The principal aperture is always large and conspicuous on its more or less produced neck and is sometimes furnished with a thickened collar. The secondary or basal aperture hardly exists, as such, at all. In many specimens the basal end is produced into a pronounced nipple, which may or may not be pierced; in other specimens, it presents an unbroken rounded extremity.

These points of difference, especially the last mentioned, raise the questions whether (1) the specimens represent more than one species, and (2) whether they are proper to *Hippocrepinella*. We think the second point must be left for final decision when more material is available, but having regard to the identical nature of the wall in all the specimens and its probable plastic nature when living, we attach little importance to the variations in size and shape, or even to the apparent suppression of the basal aperture.

Hippocrepinella alba is very rare everywhere, but a good many specimens, more or less fragmentary, have been obtained, the best at Sts. 45, 144, WS 154 and MS 68. Its food consists of ingested Diatom-mud, as in the case of *Hippocrepinella hirudinea*.

Its range in depth extends between 100 and 270 m.

Genus Hyperammina, Brady, 1878

85. **Hyperammina elongata**, Brady (F 72).

Four stations: 151; WS 353, 373, 523.

Very pauperate specimens at WS 523, recognizable fragments elsewhere. Always very rare.

86. **Hyperammina laevigata**, J. Wright (F 73).

One station: WS 33.

Some recognizable fragments only.

87. **Hyperammina novae-zealandiae**, Heron-Allen and Earland (F 75).

Two stations: 27, 144.

A very large specimen and a small one at St. 27, also a good specimen at St. 144: all microspheric and typical.

88. **Hyperammina subnodosa**, Brady.

Hyperammina subnodosa, Brady, 1884, FC, p. 259, pl. xxiii, figs. 11–14.
Hyperammina subnodosa, Cushman, 1920, CAE, p. 5, pl. i, figs. 1, 2.

Thirteen stations: 20, 27, 45, 123, 126, 131, 140, 144, 148; WS 33, 42, 154, 348.

Frequent at many of the stations, where its large size makes it a very conspicuous object. The finest series was obtained at Sts. 20, 126 and 144, where specimens up to an inch in length occur. These largest specimens are nearly always much curved, and exhibit a tendency to become narrow at the oral extremity, which is always narrower than the aboral end next to the proloculum. The proloculum varies in different specimens, being sometimes quite inconspicuous but usually a pronounced knob. These differences may represent the microspheric and megalospheric forms. The characteristic constrictions of the tube are extremely marked at St. 144, where some of the specimens might almost be described as jointed. The construction is the same everywhere, fine sand grains and sponge spicules are used in about equal proportions, the spicules predominating towards the apertural end. The tubes are often covered with other sessile Foraminifera, belonging to many genera and even the interior of dead specimens forms a retreat for sessile forms.

Genus **Saccorhiza**, Eimer and Fickert, 1899

89. **Saccorhiza ramosa** (Brady) (F 56A).

Saccorhiza ramosa, Cushman, 1910, etc., FNP, 1910, p. 65, fig. 81.
Hyperammina ramosa, Heron-Allen and Earland, 1922, TN, p. 86, pl. i, fig. 13.

Seven stations: WS 63, 334, 336, 353, 429, 522, 523.

Fragments are not uncommon at these stations all of which are in deep water, the depths ranging between 1697 and 4041 m.

At WS 522 a large and very fine specimen occurs, ramifying over the surface of a stone to which the branching tubes are very lightly attached.

By an oversight this species was placed out of order (No. 56A) in the Falkland Report. It should have been No. 76A.

Genus **Psammatodendron**, Norman, 1881

90. **Psammatodendron indivisum**, Heron-Allen and Earland (F 77).

Two stations: 123; WS 33.

A few detached tubes which appear to belong to this species, the best at WS 33.

Genus **Marsipella**, Norman, 1878

91. **Marsipella elongata**, Norman.

Marsipella elongata, Norman, 1878, GH, p. 281, pl. xvi, fig. 7 (3 on plate).
Marsipella elongata, Brady, 1884, FC, p. 264, pl. xxiv, figs. 10–19.
Marsipella elongata, Heron-Allen and Earland, 1922, TN, p. 90, pl. iii, figs. 10–12.

One station: WS 351.

A single specimen only.

92. **Marsipella cylindrica**, Brady (F 78).

Four stations: WS 33, 334, 353, 429.

Fragments of varying sizes are not uncommon, especially at WS 33, which was the best station. Here all the specimens used spicules, principally or entirely, for building, and one specimen bears the terminal crown, which we figured in 1912. At WS 429 some specimens used spicules and others mineral grains only, as also did the specimens at WS 334 and 353.

Genus **Rhabdammina**, M. Sars, 1869

93. **Rhabdammina discreta**, Brady (F 80).

One station: WS 365.

A few fragments from this station, depth 3219 m.

Genus **Rhizammina**, Brady, 1879

94. **Rhizammina algaeformis**, Brady.

> *Rhizammina algaeformis*, Brady, 1879, etc., RRC, 1879, p. 39, pl. iv, figs. 16, 17; 1884, FC, p. 274, pl. xxviii, figs. 1–11.
> *Rhizammina algaeformis*, Flint, 1899, RFA, p. 272, pl. xv, fig. 1.

Seven stations: 20, 45; WS 50, 154, 336, 349; MS 68.

Fragments doubtfully referable to *Rhizammina* occur at these stations, but only at MS 68 was a branching fragment seen which could with any certainty be referred to *R. algaeformis*. The others are flat, unbranching, ribbon-like organisms of variable but regular width throughout, very similar to the figures of "chitinous Rhizopod-tubes, probably related to *Rhizammina*", which Brady figures (B. 1884, FC, pl. xxix, figs. 1–3). They are more or less coated with mud, Diatoms, etc., and their size, though very variable, is nearly always much less than that of *R. indivisa*, Brady. They possibly represent one or more species still to be described. At WS 154 a large worm tube was found festooned with such organisms.

Family LITUOLIDAE

Sub-family *LITUOLINAE*

Genus **Reophax**, Montfort, 1808

95. **Reophax scorpiurus**, Montfort (F 82).

Seventeen stations: 16, 20, 131, 136, 140, 144, 151, 157; 53° 00′ S, 34° 22′ W; WS 28, 66, 334, 351, 353, 373, 429, 522.

Except at WS 334, where it is frequent, this species is uniformly rare, seldom more than one or two specimens at a station. Very good specimens, however, were found at WS 66 and 353.

96. **Reophax subfusiformis**, sp.n. (Plate II, figs. 16–19).

> *Reophax scorpiurus* (*pars*), Goës, 1894, ASF, p. 25, pl. vi, figs. 166, 167.

Twenty-six stations: 14, 20, 23, 27, 30, 42, 45, 126, 131, 136, 144, 148, 149, 660; WS 18, 32, 33, 37, 42, 43, 45, 46, 154, 348, 349; Drygalski Fjord.

Test large, usually composed of four chambers only, though specimens have been observed up to six chambers. Chambers increasing rapidly in size, the last one forming the bulk of the entire test, sometimes as much as four-fifths of the whole. The chambers are turgid with sutural lines deeply depressed and are arranged on a more or less strongly curved axis, the apertures being situated near the outer edge of the curve. The final chamber is fusiform and tapering to the apertural end, which carries a prolonged neck with large round aperture. The wall is thin and smoothly finished externally, built of sand grains of varying sizes, often including some very large grains, embedded in cement. Inner surface of wall very rough and irregular. Colour grey to nearly black according to the minerals employed for building. Size varies up to 2·2 mm. in length, 0·8 mm. in greatest breadth.

This is by far the most abundant representative of the genus in the South Georgia area; very common at St. 148, common at Sts. 27, 126, 144, frequent to very rare at the remaining stations.

Goës (*ut supra*) gives a long series of figures ascribed to *R. scorpiurus*. Cushman has already separated figs. 160–3 as the types of *R. curtus*, which differs from *R. subfusiformis* in the lesser number of chambers, typically three, and the absence of a produced neck. This produced neck, which is so pronounced a feature of *R. subfusiformis*, is also typical of *R. dentaliniformis*, Brady, but the chambering of my species is much nearer *R. scorpiurus*, and indeed *R. subfusiformis* might be regarded as occupying a position intermediate between these species and combining the most prominent features of each.

The name is derived from Goës, who describes his fig. 167 as "subfusiformis, e sinu Gullmaren Bahusiae, profund. 140 met."

97. **Reophax pilulifer**, Brady (F 82A).

Three stations: 30; 53° 00′ S, 34° 22′ W; WS 523.

Extremely rare, single specimens and fragments only at these stations, the last two of which are in deep water.

98. **Reophax robustus**, Pearcey.

Reophax robustus, Pearcey, 1914, SNA, p. 1006, pl. i, figs. 6–10.

One station: WS 523.

A single young specimen with two chambers only.

99. **Reophax fusiformis** (Williamson) (F 83).

Ten stations: 14, 23, 31, 131; WS 28, 33, 42, 113, 348; MS 68.

Very rare everywhere. The best specimens at Sts. 23, 131 and WS 113.

100. **Reophax spiculifer**, Brady (Plate II, fig. 20).

Reophax spiculifera, Brady, 1879, etc., RRC, 1879, p. 54, pl. iv, figs. 10, 11; 1884, FC, p. 295, pl. xxxi, figs. 16, 17.
Reophax spiculifera, Chapman, 1914, FORS, p. 62, pl. iii, fig. 16.

Two stations: WS 429, 523.

Five specimens at WS 429 and two at WS 523, all perfectly typical. This highly selective species has a wide distribution.

101. **Reophax dentaliniformis**, Brady (F 84).

Three stations: 53° 00′ S, 34° 22′ W; WS 42, 429.

Frequent at WS 429 where the specimens are built up of rather coarse sand grains with little cement. Single specimens only at the other stations, but more neatly constructed and conforming to Brady's figure.

102. **Reophax flexibilis**, Schlumberger (F 86).

One station: WS 32.

A single fine specimen with sixteen chambers.

103. **Reophax nodulosus**, Brady (F 84A).

Six stations: 151; WS 33, 50, 334, 336, 521.

Very rare everywhere. Fragments of typical specimens of medium size at St. 151 and WS 334. Small but fairly typical at WS 50 and 336. At WS 33 and 521 fragments of a form occur which is assigned with some hesitation to *R. nodulosus*. The chambers though very variable are long as compared with their breadth, sharply constricted at the sutures and thin-walled, cement predominating over the minerals employed.

104. **Reophax distans**, Brady.

Reophax distans, Brady, 1879, etc., RRC, 1881, p. 50; 1884, FC, p. 296, pl. xxxi, figs. 18–22.
Reophax distans, Fauré-Fremiet, 1913–14, FMAF, 1913, p. 260, fig. 1; 1914, p. 2, pl. O, fig. 2.
Reophax distans, Cushman, 1918, etc., FAO, 1920, p. 12, pl. iii, figs. 5, 6.

Three stations: 53° 00′ S, 34° 22′ W; WS 63, 336.

A few fragments at each station. There can be little doubt that at WS 63 and 336 they are parts of large specimens of Brady's type, coarsely built. The fragments from 53° 00′ S, 34° 22′ W are more doubtful. They may be terminal chambers either of a more delicately constructed specimen of Brady's type, or perhaps of another and undescribed species.

105. **Reophax distans var. gracilis**, var.n. (Plate II, fig. 21).

Seven stations: 151; 53° 00′ S, 34° 22′ W; WS 334, 336, 353, 429, 522.

Test elongate, straight or perhaps slightly curved, consisting of pyriform or fusiform chambers connected by more or less elongate stolon tubes. Usually fragmentary, no specimen seen with more than two connected chambers. Wall thin, constructed of fine sand grains embedded in cement. Exterior somewhat rough. Colour pale yellow, darker at the stolons.

The description is based both on a single specimen (0·45 mm. in length) of two chambers, one of which is apparently the proloculum, and on numerous individual chambers of varying sizes and proportions. In the two-chambered specimen, the breadth of the chambers is roughly half the length (final chamber 0·2 mm. long, 0·1 mm. broad), but apparently the length increases in proportion to the size of the chamber and in the largest isolated chambers is three or four times the breadth (separate chambers measure up to 0·7 mm. long, 0·2 mm. broad).

This very fragile little organism is frequent at WS 334, and 353, rarer at the other stations, all of which are in very deep water. It is probably nearly related to *R. distans*, Brady, but is sufficiently distinctive to merit varietal rank. Even at the same station there is considerable variation in the size of the sand grains employed, with corresponding differences in the external appearance. Sometimes the sand grains are so small as to be hardly distinguishable, the surface then being neatly and smoothly finished. Otherwise they are large and the surface is rough and angular.

Fracture appears to occur always at or near the base of the chamber and not as might be expected in the middle of the stolon tube. The separate chambers thus resemble a *Lagena* with tapering neck, and bear considerable resemblance to the figures of *Lagenammina laguncula*, Rhumbler (R. 1911, FPE, p. 92, pl. i, fig. 4). Indeed, until the discovery of the specimen with two chambers, these isolated chambers were assumed to belong to that species, or to some allied form of *Proteonina*. I have no personal knowledge of Rhumbler's species, so cannot say how closely the specimens agree with his types, which were from the North Atlantic at depths of 1524–2400 m.

106. **Reophax sabulosus**, Brady.

Reophax rudis, Brady (*non* Costa), 1879, etc., RRC, p. 49.
Reophax sabulosa, Brady, 1882, FKE, p. 715; 1884, FC, p. 298, pl. xxxii, figs. 5, 6.

One station: WS 334.

One specimen from a depth of 3705 m. It is not perfect, but the characteristic thick outer coating of sand grains is well preserved.

107. **Reophax aduncus**, Brady.

Reophax adunca, Brady, 1882, FKE, XI, p. 715; 1884, FC, p. 296, pl. xxxi, figs. 23–6.
Reophax aduncus, Cushman, 1918, etc., FAO, 1920, p. 15, pl. v, fig. 1.

Two stations: 131; WS 33.

Only a single small specimen at each station.

Genus **Hormosina**, Brady, 1879

108. **Hormosina globulifera**, Brady (F 89).

One station: WS 523.

A few specimens only, mostly megalospheric single-chambered individuals.

Genus **Haplophragmoides**, Cushman, 1910

109. **Haplophragmoides canariensis** (d'Orbigny) (F 90) (Plate III, fig. 13).

Thirty-nine stations: 13, 14, 15, 20, 27, 30, 31, 42, 45, 123, 126, 131, 140, 144, 148, 149, 157, 660; WS 25, 27, 28, 31, 32, 33, 40, 41, 42, 45, 46, 50, 63, 63–4, 154, 177, 348, 357; Drygalski Fjord; MS 14, 68.

Generally distributed in the shallower stations, almost entirely absent from deep water, a depth of about 300 m. marking its limit with very rare exceptions, e.g. a single small specimen at WS 63 in 1752 m. It is very common at Sts. 126, 144, 149, WS 28 and MS 68, and only less so at Sts. 27, 148 and WS 25, 32, 42 and 50. At the majority of the stations, however, it is rare or very rare. The dominant type everywhere is an evolute flattened form of normal size; but, wherever the species is abundant, a much smaller involute form and an abnormally large form, which is also involute, occur in numbers (e.g. at Sts. 123, 140, 144, 148, WS 25 and 154, MS 68). Abnormal and encysted specimens were seen at several stations, and at St. 149 a specimen of the large form occurred with six young individuals attached. These young shells are apparently megalospheric and consist of three or four chambers. The majority of them lie near the aperture of the parent shell, which from its size (1·2 mm. diameter) is probably microspheric. They are presumably a young brood, formed outside the parent shell by the breaking up of its protoplasm into particles surrounding a nucleus, these particular young having remained in contact with the parent instead of achieving freedom.

A somewhat similar phenomenon of young individuals attached to their presumed parent shell is of fairly frequent occurrence in the *Globigerinae* and will be noticed under that genus (see p. 120).

110. **Haplophragmoides crassimargo** (Norman) (F 92).

Two stations: WS 51, 373.

Extremely rare. A very good and typical specimen at WS 51.

111. **Haplophragmoides sphaeriloculum**, Cushman (F 93).

Three stations: WS 334, 348, 353.

Extremely rare, the best specimen at WS 334.

112. **Haplophragmoides scitulum** (Brady) (F 94) (Plate III, figs. 11, 12).

Eight stations: 151; WS 48, 50, 63, 63–4, 334, 336, 351.

Very rare everywhere, the best and most typical specimens at WS 48 and 63–4. At St. 151, WS 63 and 334 the species is represented by an oval variety, with umbilical region only slightly depressed.

113. **Haplophragmoides subglobosus** (G. O. Sars) (F 95).

Ten stations: 151; WS 63, 63–4, 334, 336, 351, 353, 429, 521, 522.

Very rare everywhere except at WS 334 and 521, where the species was frequent. Some excellent specimens at WS 522, rather smaller at WS 63, 63–4 and 521, very small and starved elsewhere.

114. **Haplophragmoides glomeratus** (Brady).

Lituola glomerata, Brady, 1878, RRNP, p. 433, pl. xx, fig. 1. *Haplophragmium glomeratum*, Brady, 1884, FC, p. 309, pl. xxxiv, figs. 15–18.
Haplophragmium glomeratum, Heron-Allen and Earland, 1913, CI, p. 46, pl. ii, fig. 14.
Haplophragmoides glomeratum, Cushman, 1918, etc., FAO, 1920, p. 47, pl. ix, fig. 6.

Three stations: 136; WS 334, 429.

Very rare everywhere, but quite typical.

115. **Haplophragmoides rotulatus** (Brady).

Haplophragmium rotulatum, Brady, 1879, etc., RRC, 1881, p. 50; 1884, FC, p. 306, pl. xxxiv, figs. 5, 6.
Haplophragmoides rotulatum, Cushman, 1918, etc., FAO, 1920, p. 47, pl. ix, figs. 3, 4.

Two stations: WS 334, 351.

Rare at WS 334, where the best specimens were found, and very rare at the other station. None of the specimens is very typical.

Genus **Ammobaculites**, Cushman, 1910

116. **Ammobaculites agglutinans** (d'Orbigny) (F 96) (Plate II, fig. 22).

Eight stations: 151; WS 63, 113, 334, 351, 353, 429, 472.

Generally very rare, often represented by a single specimen. At WS 63 a single large and typical individual. At all the other stations the specimens are of the minute elongate form figured by Brady (B. 1884, FC, pl. xxxii, fig. 22). They are most numerous at St. 151, WS 334 and 472. In length they range up to 0·6 mm.

Cushman (C. 1918, etc., FAO, 1920, p. 67) has made this particular figure of Brady's a synonym for his species *Ammobaculites reophaciformis* (C. 1910, NAFP, p. 440, figs. 12–14; 1921, FP, p. 92, pl. xi, fig. 3; pl. xiv, fig. 3) on grounds which are not very evident to me. His species is stated to live in shallow water on coral reefs, and has a length up to 3·5 mm. It bears little resemblance to Brady's figure, which was drawn from a specimen from Challenger St. 5, in 1090 fathoms to the west of Gibraltar Strait. Brady's specimen is about 0·32 mm. in length and appears to be nothing more than a pauperate condition of the common type. I have no hesitation in referring the specimens to *A. agglutinans*, and attribute their small size to depth and unsuitable conditions of life. At most they are only worthy of varietal distinction.

117. **Ammobaculites americanus**, Cushman (F 97).

Twenty-two stations: 14, 16, 20, 27, 30, 45, 123, 131, 136, 144, 148, 149; WS 28, 41, 42, 45, 47, 50, 349, 357; MS 14, 68.

Widely distributed and sometimes frequent to common. It appears to be almost confined to depths between 100 and 300 m., none of the records being from less than 100 m. and only two from over 300 m. The deepest record was at St. 16 in 727 m., where a single specimen was obtained. The best stations were St. 144 (frequent) and WS 28 (common). At the last station an abnormal specimen was found in which the apertural end was surrounded with an ovate mass or cyst of loosely aggregated sand and mud. Whether this is a development from the organism, or a *post-mortem* attachment, cannot be definitely stated. The latter case is the more probable as the sand grains embodied are black as compared with the quartz in the actual test. The line of demarcation between *A. americanus*, Cushman, *A. tenuimargo*, Brady, *A. rostratus*, Heron-Allen and Earland, and *A. bargmanni*, sp.n., is very obscure in the early stages, which are practically inseparable. Only adult specimens show marked specific distinctions.

118. **Ammobaculites bargmanni**, sp.n. (Plate II, figs. 23–6).

Five stations: 27, 45, 123, 144, 148.

Test large, free, planispiral, involute; consisting of about three convolutions of chambers rapidly increasing in size and thickness. Umbilical area much depressed; seven to nine chambers in final convolution, the last chamber, or at most the last two chambers, becoming extended into a straight growth bearing the terminal aperture, a large elongate slit. Sutures depressed, peripheral edge sub-acute, becoming rounded in the final chambers. Surface smooth but unpolished, generally composed of very fine sand grains, neatly and firmly bound together without visible cement. Coarser grains are sometimes used, giving a rough exterior to the test. Walls thin, rough internally. Colour grey, the umbilical portion sometimes brown. Size, up to 3·5 mm. in diameter, sometimes even larger.

Young individuals appear to be inseparable from the young of *A. americanus*, except for the slightly depressed sutural lines. There is a tendency to abandon the usual neatness of construction in the final stages, the last chamber or two often having a few very large sand grains incorporated in the walls.

A. bargmanni appears to be a very distinctive species, linking the genera *Haplophragmoides* and *Ammobaculites*, and so perhaps demonstrating the zoological continuity of the group, and the futility of their separation. Up to the time of the formation of the last two or three chambers, the test is a typical *Haplophragmoides*, its nearest ally being apparently *H. compressum* (Goës) (= *H. emaciatum*, Brady) (G. 1882, RRCS, p. 141, pl. xii, figs. 421–3; 1896, DOA, p. 31). With the formation of these final chambers, it assumes the external characteristics of *Ammobaculites*, and bears some resemblance to *A. americanus*, from which, however, it is easily separable owing to its involute construction, depressed sutures, inflated chambers, and its size, which is nearly double that of *A. americanus*. It appears to be one of the largest recorded species in either genus.

A. bargmanni is not infrequent at a depth of 270 m. at St. 45, which is at the entrance to Cumberland Bay; it is rarer at the lesser depths of other adjacent stations. The species appears, therefore, to be confined to a very limited area. At Sts. 27 and 148, coarser material is employed for construction of the test than at the remaining stations, with the result that the specimens have a very rough and untidy appearance. At St. 144, both smooth and rough-walled specimens were noted.

The species is named after H. E. Bargmann, Ph.D., of the Discovery Staff, who has assisted me in the preparation of index, charts, etc.

119. **Ammobaculites rostratus**, Heron-Allen and Earland (Plate V, figs. 22–5).

Ammobaculites rostratus, Heron-Allen and Earland, 1929, etc., FSA, 1929, p. 328, pl. ii, figs. 14–17.

Fourteen stations: 27, 41, 45, 123, 126, 143, 149, 660; WS 28, 32, 40, 42, 63–4; MS 68.

Test free, thin-walled and rather fragile, compressed, plano-spiral and evolute. Consisting of two to three convolutions, with from five to seven chambers in the last convolution. The final chamber is produced at a tangent to the spiral and terminates in a flattened nipple with slit-shaped aperture. Umbilical region depressed on both sides, marking the area of the inner convolutions. The chambers of the last convolution are slightly inflated and do not extend to the edge of the test, which is thus furnished with a solid carina having a rounded peripheral edge. The sutural lines are generally obscure. Colour light grey, surface rough and unpolished. Walls constructed either of fine sand and mud with a considerable proportion of grey cement, or of mud without apparent cement, according to the environment. When sand grains are employed they are generally minute and of uniform size, but whether sand or mud is used, symmetrical construction is often spoiled by the inclusion of one or two large grains. The nipple-like terminal of the final chamber is more neatly constructed than the rest of the shell.

The characteristic terminal chamber presumably marks the completion of growth, as it is only found in the largest specimens. For this reason, coupled with the fragility of the test, specimens exhibiting this feature are rare. Broken and immature specimens are of frequent occurrence, and in this condition the species closely resembles *Ammobaculites americanus*, Cushman (= *Haplophragmium fontinense*, Brady *non* Terquem), to which our species is probably closely allied.

Dimensions. Length of perfect specimens 2·0–2·4 mm.; breadth 1·4–1·6 mm.

The species is very generally distributed but is never so common in occurrence as *A. americanus*. The best stations for the mud-building form are Sts. 45, 126 and 149; for the sandy form St. 27. At St. 660 and MS 68 both mud and sand-building forms occur in considerable numbers and attain large dimensions.

120. Ammobaculites tenuimargo (Brady).

Haplophragmium tenuimargo, Brady, 1882, FKE, XI, p. 715; 1884, FC, p. 303, pl. xxxiii, figs. 13–16.
Haplophragmium tenuimargo, Flint, 1899, RFA, p. 275, pl. xix, fig. 3.
Ammobaculites tenuimargo, Cushman, 1918, etc., FAO, 1920, p. 65, pl. xiii, figs. 3–5.

Four stations: 27, 144, 148; WS 429.

Always very rare. The best and most typical specimen was found at WS 429 at a depth of 2549 m. More numerous at St. 144. All the specimens except the single one found at WS 429 are very broad in the spiral portion as compared with Brady's figure, suggesting a close relationship with *A. americanus*.

121. Ammobaculites foliaceus (Brady).

Haplophragmium foliaceum, Brady, 1879, etc., RRC, 1881, p. 50; 1884, FC, p. 304, pl. xxxiii, figs. 20–5.
Ammobaculites foliaceus, Cushman, 1918, etc., FAO, 1920, p. 64, pl. xiii, figs. 1, 2.

Three stations: 151; WS 63, 334.

Rare at WS 334 and very rare at St. 151 and WS 63. All the specimens are small and less neatly constructed than usual.

Genus **Ammomarginulina**, Wiesner, 1931

122. **Ammomarginulina ensis**, Wiesner (Plate III, figs. 1–4).

Ammomarginulina ensis, Wiesner, 1931, FDSE, p. 97, pl. xii, fig. 147.

Two stations: WS 199, 334.

Test free, much compressed, especially in the early stage which is planospiral, rather loosely coiled, and contains about two convolutions, the last convolution containing nine to ten narrow chambers. These are followed by a straight series of chambers, four to seven in number, narrow and compressed at first, tending to become more inflated towards the aperture, which is central in the early stages, sometimes becoming slightly produced and marginal in the adult form. Sutural lines curved but very indistinct, the chambers being difficult to distinguish except in balsam-mounted specimens. Constructed of rather large mineral grains firmly agglutinated, but without much visible cement; surface rather rough, colour pale straw to golden yellow.

Length, about 0·4 mm.; breadth at spiral portion ranging between 0·2 and 0·3 mm.; breadth of uniserial portion ranging between 0·1 and 0·15 mm.

Many specimens occur at WS 334 at a depth of 3705 m. This station is well to the north of South Georgia, and the absence of the species at stations intermediate between WS 334 and 199, which is far to the south, near the South Orkney Islands, is rather remarkable. Only a single specimen was noted at WS 199 at a depth of 3813 m., but the species, though never common, is of very constant occurrence in the deep water Antarctic material.

I had already described this species in MS. under the name *Ammobaculites ensis* before I became aware of Wiesner's prior publication (*ut supra*). Wiesner has created a new genus *Ammomarginulina*, of which this is the genotype. The characteristic feature of the genus is the position of the aperture, which is on the outer marginal edge, as in *Marginulina*. I had not attributed so much importance to this feature, though the general resemblance of the form to *Marginulina ensis*, Reuss, had, by a coincidence, caused me to select the same specific name as Wiesner. His definitions of the new genus and species are brief, but sufficient in connection with his figure drawn from a transparent specimen for identification with my specimens. He writes of the genus *Ammomarginulina*: "The sandy shell is spirally coiled at first, later chambers arranged in a straight line, sutures curved, aperture on the back edge". Of the species it is stated that "it bears the features of the genus. The shell wall is built up of flat mica-like mineral flakes with little cement". No dimensions, locality or frequency are given, but from the figure his specimen agrees in size with ours. As Wiesner's material was from the opposite side of the Antarctic area, the species is apparently universally distributed over the Antarctic seas.

Genus **Placopsilina**, d'Orbigny, 1850

123. **Placopsilina cenomana**, d'Orbigny (F 98).

Five stations: 45, 136; WS 51, 61, 154.

The best stations were WS 51 and 61, where many specimens of the small neat form found in British seas were observed encrusting stones. Otherwise the specimens are few and rather feeble. At St. 45 two unattached specimens were found, probably dislodged from their original host.

Sub-family *TROCHAMMININAE*

Genus **Ammolagena**, Eimer and Fickert, 1899

124. **Ammolagena clavata** (Jones and Parker) (F 99).

Three stations: WS 334, 521, 522.

Several good specimens at each station.

Genus **Tolypammina**, Rhumbler, 1895

125. **Tolypammina vagans** (Brady) (F 100).

Sixteen stations: 17, 27, 126, 136, 144, 145, 148; WS 31, 33, 51, 61, 154, 344, 353, 363, 365.

Common at WS 51 and 61, frequent at St. 17 and WS 33, but rare elsewhere. All the specimens are rather small, the best being at Sts. 27, 144 and WS 33.

Genus **Ammodiscus**, Reuss, 1861

126. **Ammodiscus incertus** (d'Orbigny) (F 101).

Eighteen stations: 14, 20, 45, 123, 131, 140, 144, 148; WS 27, 33, 40, 42, 113, 154, 348, 349, 353, 426.

Widely distributed and often fairly common, the best stations being St. 144 and WS 154. The specimens are larger and better developed with more ferruginous cement than in the Falkland area, but present the same variations as we commented on in that Report. Flat and evenly coiled specimens are very rare, the best being at Sts. 45, 148, WS 33, 42 and 353. At nearly all the other stations the specimens are more or less irregular in coiling and pass imperceptibly into *Glomospira gordialis*. None of the specimens are very large, seldom exceeding 0·3 mm. in diameter, and they are all microspheric. At WS 27 a sessile specimen was seen. All the specimens have a matt surface, i.e. there is never sufficient cement to envelop the minute sand grains. Their colour varies from white through grey to ferruginous brown.

Genus **Glomospira**, Rzehak, 1885

127. **Glomospira gordialis** (Jones and Parker) (F 102).

Twenty-nine stations: 15, 17, 27, 30, 42, 45, 123, 126, 140, 144, 149; WS 25, 27, 31, 33, 40, 41, 42, 43, 51, 61, 63, 63–4, 113, 349, 365, 426, 428; MS 14.

More generally distributed and more abundant than *Ammodiscus incertus*, from the irregularly formed local variety of which it is often hardly separable.

The typical *gordialis* in which the coiling of the tube is entirely irregular is found only at Sts. 27, 30, 140, 149, WS 25, 27, 31 and 63, MS 14. At WS 63 the specimens were highly polished owing to excess of cement, all others presenting the matt surface characteristic of the genus in this area. The typical form also occurs at WS 33, in company with the local variation akin to *A. incertus*. The best specimens, both in numbers and development, were obtained at this station.

The local variety, in which the earlier convolutions are regularly coiled as in *A. incertus* and the later convolutions very irregular, is found at all the remaining stations. Sessile forms often occur, notably at WS 51.

I have followed recent practice in assigning this species to *Glomospira*, but the difficulty of separating many of the specimens from *A. incertus* convinces me that, so far at least as *Glomospira gordialis* is concerned, the generic distinction has no real value. In my opinion this also holds good as regards many old genera revived and new genera created in recent years by systematists.

The remarks as to the colour of *Ammodiscus incertus* hold good as regards *G. gordialis* also.

128. **Glomospira charoides** (Jones and Parker) (F 103).

Six stations: 151; 53° 00′ S, 34° 22′ W; WS 334, 353, 521, 522.

Singularly rare, one specimen only at each station, all very small except at St. 151 and WS 521.

Genus **Turritellella**, Rhumbler, 1903

129. **Turritellella shoneana** (Siddall) (Plate III, figs. 9, 10).

Trochammina shoneana, Siddall, 1878, FRD, p. 46, figs. 1, 2.
Ammodiscus shoneanus, Brady, 1884, FC, p. 335, pl. xxxviii, figs. 17–19.
Turritellella shoneana, Rhumbler, 1903, ZRR, p. 283, fig. 135.
Ammodiscus shoneanus, Heron-Allen and Earland, 1913, CI, p. 49, pl. iii, fig. 6; 1922, TN. p. 110, pl. i, fig. 22.
Turritellella shoneana, Cushman, 1918, etc., FAO, 1918, p. 102, pl. xxxviii, figs. 5–7.

One station: 145.

A number of specimens were found at St. 145, but none at any other station. This may be due to the nature of the material (trawl-washings) and the shallowness of the water, 26–35 m.

All the specimens are of the minute form usually found in British gatherings and identical with such. Both megalospheric and microspheric individuals occur, the former being characterized by a globular proloculum almost equal in diameter to the subsequent coil of chambers, which consequently has nearly parallel sides. In the microspheric form, the proloculum is quite small and the test forms a slender cone. The texture is finely granular owing to the small proportion of cement employed. Colour light brown, fading into white at the oral extremity.

130. **Turritellella laevigata**, sp.n. (Plate III, figs. 5–8).

One station: WS 33.

Test free, straight or irregularly curved, cylindrical, but frequently constricted at irregular intervals, rounded at the proloculum, which often exceeds the maximum diameter elsewhere, truncate at the oral extremity, which is slightly narrowed and bears a rather large central, simple aperture. Surface smooth and highly polished owing to the large amount of cement employed. Colour pale yellow, generally rather darker at the aboral end. Convolutions variable in width and number, ranging up to twenty or more in large individuals.

Viewed as a transparent object under a high magnification, the test is seen to be constructed of very minute mineral grains embedded in an excess of cement. The walls are thin, the central columella being comparatively thick. The constrictions visible externally appear to mark stages of growth; a fresh coil is formed at the beginning of each stage, the central columella being often at a slightly different angle from the preceding one. The first convolution of the new coil is wider than the preceding and following convolution, because it embraces the apertural end of the previous growth. This gives an appearance of segmentation, but we have been unable to trace any actual septum at the point of junction. All the specimens are megalospheric.

Size up to 0·7 mm. long, 0·1 mm. broad.

T. laevigata cannot be confused with *T. shoneana*, from which it differs in the excessive quantity of cement employed, the external constrictions and the consequently varying axis of growth.

A good many specimens were found at WS 33 at a depth of 130 m. The species was not found elsewhere in the South Georgia area but occurs also at St. 175 in the South Shetlands (200 m.) and WS 482 in the same area (100 m.). See note A, Appendix, p. 132.

Genus **Trochammina**, Parker and Jones, 1860

131. **Trochammina squamata**, Jones and Parker (F 104).

Five stations: 145; WS 27, 33, 154, 334.

Rare everywhere and generally small. Sessile specimens at WS 154 and 334.

132. **Trochammina rotaliformis**, J. Wright (F 105).

Two stations: 149; WS 33.

Very rare, only one or two specimens at each station. At WS 33 the specimens are very highly convex on the dorsal side.

133. **Trochammina ochracea** (Williamson) (F 107).

Three stations: WS 41, 51; MS 14.

Extremely rare. A sessile specimen at WS 51.

134. **Trochammina inflata** (Montagu) (F 108).

Six stations: 149, 151; WS 353, 429, 522, 523.

Very rare and small, the best at WS 429.

135. **Trochammina malovensis**, Heron-Allen and Earland (F 109) (Plate IV, figs. 38–40).

Fifty-one stations: 13, 20, 23, 27, 30, 31, 42, 45, 123, 126, 131, 136, 140, 143, 144, 145, 148, 149, 151; WS 18, 25, 27, 28, 31, 32, 33, 40, 41, 42, 43, 45, 46, 47, 48, 50, 52, 63, 113, 154, 177, 334, 336, 343, 348, 349, 357, 418, 523; Drygalski Fjord; MS 14, 68.

This species has proved to be more widely distributed in the South Georgia area than was anticipated from the records which were available when it was originally described. It proves to be almost ubiquitous, often common or even very common, the best stations being 126, 144, 149; WS 25, 31–3 and 40. The species is more subject to variation than in the Falklands, the dorsal surface varying from the highly convex trochoid spiral of the original figures to an almost flat dorsal surface. These flat specimens can hardly be separated from *T. nana*. Every intermediate stage of convexity is found and the two forms often occur together, though one or the other is generally dominant. The South Georgia specimens are seldom so ferruginous in colour as the Falkland types, and at many stations the tests are normally grey. Abnormalities are very rare but a few were observed, also a case of encystment at WS 113. The range of the species extends between depths of 26 and 3705 m., but it is most at home in moderate depths below 200 m. and becomes very rare and small in deep water.

136. **Trochammina nana** (Brady) (F 110).

Two stations: 151; WS 28.

A single typical specimen only at each station.

137. **Trochammina bradyi**, Robertson (F 111).

Three stations: 131, 151; WS 334.

Very rare, never more than one or two specimens at each station.

138. **Trochammina nitida**, Brady.

Trochammina nitida, Brady, 1879, etc., RRC, 1881, p. 52; 1884, FC, p. 339, pl. xli, figs. 5, 6.
Trochammina nitida, Goës, 1894, ASF, p. 30, pl. vi, figs. 225–30.
Trochammina nitida, Heron-Allen and Earland, 1916, FWS, p. 228, pl. xl, figs. 19–21.
Trochammina nitida, Cushman, 1918, etc., FAO, 1920, p. 75, pl. xv, fig. 2.

Ten stations: 16, 23, 31, 42, 136, 144; WS 43, 46, 50, 349.

Very rare, but good specimens at most stations, the best at St. 16 and WS 349.

139. **Trochammina turbinata** (Brady).

Haplophragmium turbinatum, Brady, 1879, etc., RRC, 1881, p. 50; 1884, FC, p. 312, pl. xxxv, fig. 9.
Trochammina turbinata, Eimer and Fickert, 1899, AVF, p. 695; Cushman, 1918, etc., FAO, 1920, p. 81, pl. xvii, fig. 2.

Thirteen stations: 23, 31, 131; WS 37, 40, 42, 43, 46, 50, 63–4, 334, 349, 353.

Very rare and very small; the best at WS 42, 50 and 349. Seldom more than one or two specimens at a station.

140. **Trochammina globigeriniformis** (Parker and Jones) (F 110 A).

Five stations: 14; WS 40, 334, 351, 429.

Very rare and usually very small. The only good specimens at WS 429.

Genus **Globotextularia**, Eimer and Fickert, 1899

141. **Globotextularia anceps** (Brady) (F 112).

Two stations: 131; WS 523.

Only a single specimen at each station.

Genus **Ammosphaeroidina**, Cushman, 1910

142. **Ammosphaeroidina sphaeroidiniformis** (Brady).

Haplophragmium sphaeroidiniforme, Brady, 1884, FC, p. 313.
Haplophragmium sphaeroidiniforme, Chapman, 1907, TFV, p. 24, pl. iii, figs. 50–1.
Ammosphaeroidina sphaeroidiniformis, Cushman, 1910, etc., FNP, 1910, p. 128, fig. 202; 1918, etc., FAO, 1920, p. 87, pl. xvii, fig. 5.

One station: WS 334.

A single small specimen.

Genus **Ammochilostoma**, Eimer and Fickert, 1899

143. **Ammochilostoma galeata** (Brady).

Trochammina galeata, Brady, 1879, etc., RRC, 1881, p. 52; 1884, FC, p. 344, pl. xl, figs. 19–23.
Ammochilostoma galeata, Eimer and Fickert, 1899, AVF, p. 692, fig. 39.
Ammochilostoma galeata, Cushman, 1910, etc., FNP, 1910, p. 127, figs. 198–201; 1918, etc., FAO, 1920, p. 85.

One station: WS 334.

A single specimen.

144. **Ammochilostoma pauciloculata** (Brady).

Trochammina pauciloculata, Brady, 1879, etc., RRC, 1879, p. 58, pl. v, figs. 13, 14; 1884, FC, p. 344, pl. xli, figs. 1, 2.
Ammochilostoma pauciloculata, Eimer and Fickert, 1899, AVF, p. 692.
Ammochilostoma pauciloculata, Cushman, 1910, etc., FNP, 1910, p. 126, fig. 197; 1918, etc., FAO, 1920, p. 86.

Two stations: 151; WS 334.

Several excellent specimens at these stations.

145. **Ammochilostoma ringens** (Brady).

Trochammina ringens, Brady, 1879, etc., RRC, 1879, p. 57, pl. v, figs. 12 *a*, *b*; 1884, FC, p. 343, pl. xl, figs. 17, 18.
Trochammina ringens, Flint, 1899, RFA, p. 281, pl. xxvii, fig. 1.
Ammochilostoma ringens, Eimer and Fickert, 1899, AVF, p. 692.
Haplophragmoides ringens, Cushman, 1910, etc., FNP, p. 107, fig. 166; 1918, etc., FAO, 1920, p. 49, pl. ix, fig. 2.

One station: WS 351.

Only a single specimen, quite typical except as regards the aperture, which is on the inner edge of the final chamber, but not above the edge and separated from the previous convolution. This abnormality gives the shell a pseudo-isomorphism with *Pullenia subcarinata*.

Genus **Nouria**, Heron-Allen and Earland, 1914

146. **Nouria harrisii**, Heron-Allen and Earland (F 113 A) (Plate III, figs. 14–16).

One station: WS 33.

Quite a number of excellent specimens were found at this station. They vary greatly in size, ranging between 0·3 and 0·8 mm. in length, and are rather less broad than the type. Otherwise they agree very well, though there is a greater tendency to use broken spicules and more cement, and to employ mineral grains for filling in odd crannies, especially at the base of the test. The projecting basal spicules are very pronounced in some of the specimens.

Sub-family *LOFTUSINAE*

Genus **Cyclammina**, Brady, 1876

147. **Cyclammina cancellata**, Brady (F 114).

Nine stations: 151; WS 63, 334, 336, 351, 418, 426, 429, 521.

Very rare, but good specimens of both megalospheric and microspheric forms, the best at WS 334 and 336. With the exception of WS 418, where a single microspheric individual was found at a depth of 227 m., all the records are from deep water between 1170 and 3780 m.

148. **Cyclammina orbicularis**, Brady.

Cyclammina orbicularis, Brady, 1879, etc., RRC, 1881, p. 53; 1884, FC, p. 353, pl. xxxvii, figs. 17–19.
Cyclammina orbicularis, Cushman, 1910, etc., FNP, 1910, p. 113, fig. 173; 1918, etc., FAO, 1920, p. 57, pl. xi, figs. 7–9.

One station: WS 334.

Two rather small specimens from 3705 m. at this station.

Sub-family *SILICININAE*

Apart from certain fossils of which we have little personal experience, the existence of really siliceous Foraminifera has always appeared to be a matter of uncertainty. A statement by Brady (B. 1884, FC, pp. 100, 131) is probably responsible for the opinion expressed by Lister (L. 1903, F, p. 53) and Cushman (C. 1928, F, pp. 11, 144, 148) that tests of nearly pure silica may be developed under deep-sea conditions. Writing of the organisms found at Challenger St. 238, in the North Pacific, at a depth of 3950 fathoms, Brady says: "*Miliolae* were the only representatives of the calcareous forms, and the shells of these were no longer calcareous, but consisted of a thin film of homogeneous silica, unaffected by acids, and iridescent when first taken out of spirit.... A few *Miliolae*...were found to be unaffected by acids, and, upon further examination, it became apparent that the normal calcareous shell had given place to a delicate homogeneous siliceous investment". It would appear from this that Brady had actually dealt with these specimens; but Heron-Allen (H.-A. 1915, RPF, pp. 264 and 272) states, on the authority of Sir John Murray, that the specimens examined on board the 'Challenger' were not preserved, and that Brady's statement was made on the strength of Murray's notes, and not from his personal knowledge of actual specimens.

It is almost certain that the objects seen by Murray were chitinous linings such as are common to all Foraminifera. At any rate, so far as we are aware, no one has subsequently described recent siliceous Foraminifera, although chitinous specimens have been observed in both deep and shallow waters by many persons, ourselves included. The discovery of truly siliceous Foraminifera in recent dredgings is therefore a matter of more than ordinary interest.

In the first place let us define the term "siliceous" as meaning "capable of resisting the action of strong acids without structural change". There are many Foraminifera belonging to various groups which, on superficial examination, might be considered siliceous, but which will not withstand this test. All the Astrorhizidae and Lituolidae make more or less use of siliceous particles in the construction of their agglutinate tests, encrusting the chitinous membrane, which forms their basic structure, with sand grains embedded in a cement secreted by the animal, which contains varying proportions of silica, ferric oxide, and carbonate of lime. Moreover, many species of Miliolidae are in the habit of encrusting their normally calcareous tests with sand grains of varying sizes, often in such abundance as to conceal the calcareous structure. But the apparently siliceous tests of the Miliolidae are instantly dissolved with effervescence on the addition of acid, while the ferruginous cement of the agglutinate forms, almost without exception, breaks down under the prolonged action of the acid. It is true that Brady (B. 1884, FC, p. 286) states that "in rare instances silica or some siliceous compound is employed, either by itself or in conjunction with other mineral substances", but the only example he gives is *Reophax nodulosus*, of which he says: "The incorporating medium is more or less siliceous, sometimes to such a degree that large specimens, half an inch or an inch in length, preserve their form after all the calcareous and ferruginous constituents have been removed by means of strong acids, and still retain sufficient firmness to bear handling without injury". This exception can hardly be said to affect the general rule that acid destroys agglutinate Foraminifera.

The history of the organisms, which we are now describing, begins in 1913, when Fauré-Fremiet (F. 1913–14, FMAF, p. 4, pl. O, fig. 5) figured and described an organism from the Antarctic, which he assigned to *Miliolina alveoliniformis*, Brady, a well-known coral-reef species. Apart from the fact that Fauré-Fremiet's specimens had agglutinate tests and a cribrate aperture, it is clear that they had little in common with Brady's species. Fauré-Fremiet seems to have had doubts as to his identification, and raises the question as to whether his organism is not a true arenaceous form, isomorphous with Brady's species. Fauré-Fremiet informs us that his mounted specimens of *Miliolina alveoliniformis*, Brady, have been mislaid, and are probably lost, but, having refreshed his memory by reference to his paper, he has no doubt whatever that his figure No. 5 B represents the oral end of his specimens, and that the characteristics there shown were constant and apparently quite distinct from the normal milioline aperture.

We must, therefore, accept the position that there is a species in the Antarctic answering to Fauré-Fremiet's description and figures, and characterized by a cribrate aperture. As the attribution of the 'Pourquoi-Pas?' specimens to *Miliolina alveoliniformis*, Brady, cannot be upheld, we suggest the new name *Miliammina cribrosa* for Fauré-Fremiet's type.

In 1914 Chapman (C. 1914, FORS, p. 59, pl. i, fig. 7) described and figured under the name *Miliolina oblonga* var.n. *arenacea* some specimens from the Ross Sea in the Antarctic. He described his organism as "quite a constant form", differing only from the porcellanous type of Montagu in the finely arenaceous material of the test. He also remarked that no porcellanous specimens were found in the same dredgings, and that his organism is readily distinguishable from *Miliolina agglutinans* (d'Orbigny), which is an agglutinate species.

Chapman's variety has since been designated as the genotype of the genus *Miliammina* by Professor T. D. A. Cockerell under the name *Miliammina arenacea* (Chapman). (See correspondence in *Nature*, June 28 and September 20, 1930.)

In 1922 we published a report on the Foraminifera of the Terra Nova Antarctic Expedition (H.-A. and E. 1922, TN, p. 66) in which we recorded that *Miliolina oblonga* var. *arenacea*, Chapman (synonym *Miliolina alveoliniformis*, Fauré-Fremiet *non* Brady) was the most typical Miliolid of the Terra Nova Antarctic collections, and that it presented a considerable range of form. Although a minute examination of the test was made to ascertain its constituents, no doubts were then entertained as to its milioline nature, and consequently no chemical tests were employed. Nor did we attempt to separate the different variations, which were all listed under Chapman's name.

In connection with the examination of the Discovery material, it soon became apparent that an organism similar to Chapman's was a typical constituent of the muds in the South Georgia area, where it was found in great variety in nearly every sounding from moderate depths. In the course of experiments to determine the proportion of calcareous matter in the test (the South Georgia muds being almost entirely mineral and diatomaceous), we found to our surprise that there was none. Immersions in strong nitric acid under the microscope produced no effervescence, nor did 24 hours' immersion in acid affect the constitution or solidity of the test. It became evident, therefore, that we were not dealing with a *Miliolina* at all, but with an entirely new organism, for which we proposed the generic name *Miliammina* (= sandy or siliceous "Milioliform" isomorph).

Miliammina is evidently closely related to a fossil organism recently described by Cushman and Church (CC. 1929, CFC, p. 502, pl. xxxvi, figs. 10–12) from the Upper Cretaceous of California, under the generic name *Silicosigmoilina*. The wall is described as finely arenaceous, with siliceous cement on which the strongest acid makes no impression. The chambers are on a sigmoiline plan, and it is apparently isomorphous with *Sigmoilina* in the porcellanous group, except for its simple aperture which lacks the tooth found in the calcareous genus. It is referred to the Silicinidae, a family established by Cushman in 1928 (*ut supra*) for the reception of the fossil genera *Silicina*, Bornemann, 1874, *Rzehakina*, Cushman, 1927, *Involutina*, Terquem, 1862, and *Problematina*, Bornemann, 1874. In the definition of the family it is stated that the wall is arenaceous, "usually siliceous, sometimes partly calcareous". Of the four genera, *Rzehakina* seems to have little in common with the others, but its structural plan is certainly near that of *Silicosigmoilina*, and its wall is siliceous. To what extent the other genera would withstand testing with acid we cannot say, but *Involutina* at least has always been regarded as largely calcareous, and is included by Brady in his sub-family Endothyrinae.

Miliammina is evidently one of the Lituolidae in Brady's system of classification, but is not easily placed in that family. The sub-family Trochammininae includes many genera, which have little obvious relationship to each other, though all characterized by neatly agglutinate tests. Many of them are isomorphous with other genera of porcellanous and hyaline Foraminifera. In this connection it is noteworthy that no true isomorph of that large and important porcellanous sub-family, the Miliolininae, has been known until recently. *Miliammina*, *Silicosigmoilina*, and *Rzehakina* will now to some extent fill this gap, and as they agree in the siliceous constitution of their cement as contrasted with the highly ferruginous cement characteristic of the Trochammininae, we propose to establish a new sub-family of the Lituolidae, "Silicininae", for the reception of these three genera. The Silicininae may be defined as having thin agglutinate tests consisting of numerous chambers, non-labyrinthic, arranged on a milioline plan, and furnished with a terminal aperture, with or without a tooth, the wall composed of minute minerals and Diatoms embedded in an excess of siliceous cement, with smooth or polished exterior, and smooth interior, surfaces.

Genus **Miliammina**,[1] Heron-Allen and Earland, 1930

Test free, chambers arranged on a triloculine or quinqueloculine plan; wall imperforate, composed of very minute mineral fragments embedded in an excess of siliceous cement, smooth or polished, rarely rough. Aperture terminal, furnished with a tooth, perhaps sometimes cribrate.

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[1] See note B, Appendix, p. 132.

Wiesner, in his recent monograph on the Foraminifera of the German South Polar Expedition (W. 1931, FDSE), does not record or figure any specimens which can be identified with *Miliammina*. This is all the more noteworthy as Wiesner was quite familiar with our Terra Nova Report (see p. 54, FDSE, *et passim*) and his material came from approximately the same area as much of the Terra Nova material, in which the genus was plentiful.

149. **Miliammina oblonga**, Heron-Allen and Earland (Plate III, fig. 17; Plate V, figs. 1–5, 7, 8).

Miliammina oblonga (Chapman), Heron-Allen and Earland, 1929, etc., FSA, 1930, p. 41, pl. i, figs. 1–6, 22–3.

Forty-seven stations: 13, 14, 20, 23, 27, 30, 31, 42, 45, 123, 126, 129, 131, 136, 140, 143, 144, 148, 149, 660; WS 18, 25, 27, 28, 32, 33, 37, 40, 41, 42, 43, 45, 46, 47, 48, 50, 52, 63, 63–4, 113, 154, 348, 349, 357; Drygalski Fjord; MS 14, 68.

Test regularly quinqueloculine; chambers tubular, larger at the aboral extremity; peripheral edge rounded to sub-acute; sutural lines almost flush in the young stage, becoming more or less depressed with increasing size of shell. Aperture crescentiform at extremity of final chamber, sometimes on a somewhat produced neck, with or without a reverted collar, furnished with a small simple tooth. Wall thin, composed of minute mineral grains embedded in an excess of siliceous cement, smooth, often polished, in which case the mineral particles of which it is partly composed are more distinct. Colour variable from very light to dark grey, rarely brown, or affected by the colour of the mineral particles employed. Size very variable in different localities. Young individuals have been seen only 0·125 mm. in length, but average well-developed tests are about 0·40–0·50 mm. in length, 0·20 mm. in breadth, 0·15 mm. in thickness. The thickness of the wall in an adult shell is estimated at 0·005–0·010 mm., and the largest mineral flakes employed by the South Georgian specimens rarely exceed these dimensions. Elsewhere larger mineral flakes are used, as we noted in 1922 (*ut supra*). In the South Georgian material, diatomaceous debris appears to be used to some extent in the construction of the test, contrary to our experience with the Terra Nova specimens, in which only mineral matter could be detected (H.-A. and E. 1922, TN, p. 67). But it is very difficult to verify the nature of the minute constituents of the test.

Almost universally distributed, *M. oblonga* is probably the commonest and most characteristic rhizopod of the South Georgia area, occurring in more or less abundance in nearly every coastal sounding. It reaches its optimum development, both as to size and numbers, in moderately shallow water. The best stations are Sts. 20, 126, 144, WS 28, 33, 42 and 154; but occasional small specimens have been found down at a depth of 1752 m. at WS 63, beyond which depth it has not been seen in any of the soundings examined. The species is subject to considerable variation, mainly owing to differences in the rotundity of the tubular chambers, with corresponding changes in the sutural depressions and peripheral angles.

The original type of Chapman, *M. arenacea* (Chapman), does not occur in the

South Georgian material, but appears to be confined to the Antarctic area and will be dealt with in our report on the same. A figure of *M. arenacea* is given for comparison (Plate V, fig. 6).

It may be mentioned here that the range of *M. oblonga* is now known to extend beyond the ice-area. It occurs in material from St. 6 off Tristan d'Acunha (80–140 m.) and from WS 4 off South-west Africa (40 m.).

150. **Miliammina obliqua**, Heron-Allen and Earland (Plate V, figs. 9–14).

Miliammina obliqua, Heron-Allen and Earland, 1929, etc., FSA, 1930, p. 42, pl. i, figs. 7–12.

Forty-six stations: 14, 15, 20, 23, 27, 28, 30, 31, 41, 42, 45, 123, 126, 129, 131, 140, 143, 144, 148, 149, 660; WS 25, 28, 32, 33, 37, 40, 41, 42, 43, 45, 46, 47, 48, 52, 63, 63–4, 113, 154, 348, 349, 357, 418; Drygalski Fjord; MS 14, 68.

Test quinqueloculine, with tubular chambers broader at the aboral ends, the early chambers lying transversely across the centre of the test. Sutural lines depressed and peripheral edge rounded. Aperture crescentiform, usually flush with the terminal end of the test, sometimes on a slightly produced neck with collar, furnished with a minute simple tooth. Walls thin and smooth, sometimes polished, embodying the fine mineral grains which appear to be somewhat larger than in *M. oblonga*. Colour varying from nearly white to dark grey, occasionally brownish. Size variable, but never attaining the proportions of *M. oblonga*. Average length 0·30–0·35 mm., breadth 0·15–0·18 mm., thickness 0·12 mm.

This little form, which frequently, but not invariably, occurs in company with *M. oblonga*, differs from that species mainly in the transverse disposition of the central chambers. It may be considered to be isomorphous with *Miliolina bosciana* (d'Orbigny), and occupies the same position with regard to *Miliammina oblonga*, as *Miliolina bosciana* does to *Miliolina oblonga* (Montagu). Its distribution is probably co-extensive with that of *Miliammina oblonga*, as it was found in the Terra Nova material and at Kerguelen.

M. obliqua is practically co-extensive in its distribution in the South Georgia area with *M. oblonga*, but it is nowhere quite so common, and there are stations at which one or other species appears exclusively, though as a rule the best specimens of each are found at the same stations, notably St. 126, WS 28 and 154.

151. **Miliammina lata**, Heron-Allen and Earland (Plate III, fig. 17 and Plate V, figs. 15–19).

Miliammina lata, Heron-Allen and Earland, 1929, etc., FSA, 1930, p. 43, pl. i, figs. 13–17.

Nineteen stations: 13, 14, 16, 31, 126, 131, 136, 145; WS 28, 32, 33, 37, 40, 42, 50, 51, 52, 348; MS 68.

Test quinqueloculine, but frequently with very little exposure of the earlier chambers, so little, in fact, that to a casual inspection the test appears triloculine. Chambers inflated, broadening at the aboral end, broadly rounded at the periphery. Sutural lines flush or only slightly depressed. Aperture rather small, crescentiform, with slightly reverted collar, situated on the end of the terminal chamber (never on a produced neck), furnished with a simple tooth. Wall rather thick, smooth, rarely polished, containing fine mineral particles in an excess of siliceous cement. Colour light grey. Size varying between 0·30–0·45 mm. in length, 0·20–0·32 mm. in breadth, and 0·13–0·22 mm. in thickness.

This is a very distinctive species and may be considered isomorphous with *Miliolina subrotunda* (Montagu).

M. lata is much rarer in the South Georgian material than either *M. oblonga* or *M. obliqua*, both as regards the number of stations at which it occurs and its relative abundance. It nowhere forms a dominant aspect in the material as the forementioned species frequently do, and generally speaking is rare. But it occurs frequently at WS 32 and 37, and very fine and typical specimens were found at other stations, notably St. 136 and WS 42 and 348. The deepest record is at St. 16 in 727 m., where only a small specimen was obtained, the species evidently favouring shallower waters than its relatives. At WS 32 a very extraordinary abnormality was found (Plate III, fig. 17) in which a specimen of *M. lata* was fused with one of *M. oblonga*, the latter projecting vertically to a height of 0·2 mm. from the centre of the lateral side of the former.

Miliammina lata occurs at seven of the ten Terra Nova stations from which we recorded *Miliolina oblonga* var. *arenacea*, so it may be presumed that the species is universally distributed in the Antarctic, like *M. oblonga* and *M. obliqua*.

We figure an abnormal specimen from WS 50, at a depth of 230 m., characterized by the prolongation of the final chamber into an enveloping curve terminated by a very large aperture (Plate V, fig. 18). Such abnormalities are of frequent occurrence in gatherings of its porcellanous isomorph, *Miliolina subrotunda* (Montagu).

Family TEXTULARIIDAE

Sub-family *TEXTULARIINAE*

Genus **Spiroplectammina**, Cushman, 1910

152. **Spiroplectammina biformis** (Parker and Jones) (F 115).

Twelve stations: 28, 144, 149; WS 32, 33, 41, 42, 46, 348; Drygalski Fjord; MS 14, 68.

Rare or very rare everywhere, but very good specimens at Sts. 144, 149, WS 32 and 41. An exceptionally large specimen at WS 32. The specimens everywhere are of the normal type, the very thin form recorded from the Falklands does not occur.

Genus **Textularia**, Defrance, 1824

153. **Textularia agglutinans**, d'Orbigny (F 116).

One station: WS 353.

A single very small but otherwise typical example from a depth of 4041 m.

154. **Textularia abbreviata**, d'Orbigny (F 118).

One station: WS 521.

A single small specimen from 3780 m. is attributed with some hesitation to this species. It is far from typical, the edges being rounded and the median line depressed.

155. **Textularia wiesneri**, sp.n. (Plate III, figs. 18–20).

Textularia parvula, Wiesner (*non* Cushman), 1931, FDSE, p. 98, pl. xiii, fig. 152.

Five stations: 144, 145, 151; WS 33; MS 14.

Test minute, elongate, often twisted, consisting of between eight and fourteen pairs of rather inflated chambers. Sutures flush at commencement, becoming depressed. Edge lobulate, especially at the oral end. Built of fine sand with much cement. Aperture a normal transverse slit. Colour brown. Length up to 0·4 mm., breadth 0·12 mm., thickness 0·07 mm.

Wiesner (*ut supra*) figures a small *Textularia*, which does not agree with Cushman's description or figures of *T. parvula*, but represents admirably a species which occurs both in South Georgia and in the Antarctic material, and is therefore probably widely distributed over the whole Antarctic area, as Wiesner's records are from the opposite side of the Antarctic Continent. He records the discovery of both megalospheric and microspheric specimens.

Cushman figures both stages of *T. parvula*. His figure purporting to represent the microspheric form is very similar to Wiesner's figure and our own megalospheric form, but his figure of the megalospheric form does not resemble either Wiesner's specimens or our own. Cushman's species is from the Caribbean Sea.

T. wiesneri is rare, or very rare, in the South Georgian material, most numerous at WS 33. It appears to be more frequent at some Antarctic stations.

It is not very readily distinguishable, at least in the megalospheric form, from *T. tenuissima*, as the rounded megalosphere bears some resemblance to the primary spiroplectine coil or planispire of that species. The brown colour, however, is in strong contrast to the silvery grey of *T. tenuissima*, and of course, when viewed by transmitted light, it is readily distinguishable, owing to its large proloculum and the invariable absence of a primary planispire.

156. **Textularia tenuissima**, nom.n. (Plate III, figs. 21–30).

Textularia elegans, Lacroix, 1932, TPCM, p. 8, figs. 4 and 6 (not fig. 5).

Twenty-five stations: 15, 30, 42, 45, 144, 149, 660; WS 28, 32, 33, 37, 40, 41, 42, 47, 63–4, 154, 334, 343, 348, 349, 353, 429; Drygalski Fjord; MS 68.

Test minute, very elongate, straight or slightly curved, oval in section, early chambers closely coiled in both megalospheric and microspheric forms, the initial end being rounded in the former and more or less pointed in the latter; tapering very gradually to the oral extremity, which is the thickest portion of the test, and rounded; edge straight for the first half of the shell, then becoming slightly lobulate, rounded throughout; chambers very numerous, up to twelve or more pairs following the initial spiral, distinct, regularly increasing in size and thickness, finally becoming slightly inflated; sutures distinct, depressed; aperture distinct, a curved slit on the inner edge of the terminal chamber; wall thin and smoothly finished, built of very minute mineral grains and other particles, attached in a single layer to the chitinous membrane and with little sign of interstitial cement; colour light grey, often silvery, very rarely tinged with ferruginous cement.

Megalospheric: length up to 0·4 mm., breadth up to 0·1 mm.

Microspheric: length up to 0·5 mm., breadth up to 0·1 mm., thickness 0·06 mm.

This very delicate and distinctive little species is widely distributed in the shallower waters of South Georgia between depths of 130 and 318 m., and also in many Antarctic gatherings. A few doubtful fragments and a single small specimen were seen in deeper water at WS 343 in 2856 m.

It is common at St. 144 and WS 32, frequent at St. 45, rare, or very rare, elsewhere, though owing to its small size and fragility it may perhaps be more abundant than it seems at some stations. It varies considerably in size and development, the dimensions given above being the maxima for South Georgia.

The species is apparently trimorphic, two very distinct megalospheric forms are to be found. One (A 1) is much shorter and has fewer chambers than the other, but the initial spiral is large and neatly rounded. The other megalospheric form (A 2) has the apex almost as acutely pointed as in the microspheric form, and is equally long.

The microspheric form appears to be acutely pointed. When examined in fluid some specimens are seen to possess a complete initial spiral coil or planispire, while others have apparently only a single apical chamber, the outermost chambers of the spiral being worn away. A similar feature in *T. sagittula*, Defrance, has been observed by Lacroix (L. 1929, TS, pp. 1–12, figs. 1–10) and confirmed by us (H.-A. and E. 1930, FPD, p. 72).

On this analogy, I propose to refer my specimens to *Textularia* rather than to *Spiroplectammina*, in which the initial planispire is distinct in both forms.

After the foregoing description of what appeared to be a new species had been written and was awaiting the press, Dr E. Lacroix of Lyons published a paper on the Textulariidae of the Mediterranean Continental Shelf. My attention was at once arrested by one of his new species, *Textularia elegans* (L. 1932, TPCM, p. 8, figs. 4–6), as his figure of the microspheric form was in general agreement with my specimens, except as regards size, the Mediterranean specimens attaining little more than half the maximum dimensions of those from South Georgia.

I sent specimens from the material to Dr Lacroix, who has no doubt as to their identity with his species. He has been so good as to supply me with a Mediterranean specimen for comparison.

Apart from the difference in size, there appears to be little doubt as to the identity of the organisms; the formation and number of chambers are the same, although the texture of the shell is somewhat different. The Mediterranean specimens have a more compact arrangement of the mineral particles, ferruginous cement uniting the grains being visible, when the specimen is examined as a transparent object under a high power. In the South Georgian specimens, there is no visible cement and the minute mineral grains appear to be attached directly to the chitinous membrane, often with gaps between the grains.

These, however, appear to be but trifling differences when compared with the numerous points of agreement, and I should have accepted Lacroix's specific name *elegans* for our South Georgian specimens, but for the fact that it has been anticipated by Hantken for an entirely different but typical *Textularia*, *Plecanium elegans* (H. 1868, KTF, p. 83, pl. i, fig. 5). This necessitates the abandonment of Lacroix's specific name, and I propose the new name *tenuissima*, which I had already adopted for the South Georgian specimens, as a substitute.

Textularia tenuissima

	Proloculum	Pairs of chambers	Length	Breadth	Observations
St. 149 (South Georgia)	0·008?	11	0·184	0·052	A typical example of my *T. elegans*. Form B
	0·008	10 + 1 final	0·212	0·060	Form B
St. 30 (South Georgia)	0·012	8	0·248	0·068	Form A 2—with planospire
	0·008	11 + 1 final	0·284	0·060	Form B—with planospire
	0·016	8	0·328	0·080	Form A 2—with planospire. Proloculum difficult to measure.
	0·012	11	0·392	0·072	Form A 2—with planospire
WS 494 A (Antarctic)	Length 0·020 Breadth 0·0185	9 + 1 final	0·280	0·076	Form A 1—without planospire
	0·020	10 + 1 final	0·284	0·080	
	0·024	10 + 1 final	0·292	0·080	
	0·020	8 + 1 final	0·200	0·068	
St. 144 (South Georgia)	0·024	5 + 1 final	0·320	—	Five chambers in planospire. From the size of the proloculum probably Form A 1
WS 41 (South Georgia)	0·020?	7 + 1 final	0·340	—	Five chambers in planospire. The proloculum is wrinkled, almost quadrangular. Its dimensions vary between 0·016 and 0·018 mm. and if smoothed out would perhaps measure 0·020 mm. Regarded doubtfully as Form A 2

Lacroix (*ut supra*, fig. 5) figures what is described as the megalospheric form of his species. It is extremely rare, only two specimens having been found. They have no initial spiral and the angle of the sutures is not the same as in his figures of the microspheric form (figs. 4, 6). I regard this figure as a distinctive and genuine *Textularia*, possibly a new species, but, in any case, unconnected with his microspheric specimens.

In other words, it would appear that the megalospheric form is still undiscovered in the Mediterranean.

In South Georgia, on the other hand, the megalospheric form, in one or other of its two conditions, occurs in some abundance, though, contrary to the usual rule, it is less common than the microspheric form.

Dr Lacroix has been so good as to measure the proloculum of some of my specimens and has furnished me with the table on p. 97. (In counting the pairs of chambers those round the proloculum forming the planispire are disregarded.)

Textularia tenuissima is no doubt a very widely distributed form, and its discovery may be expected at many localities intermediate between Lacroix's stations off Monaco and our own South Georgian localities. I am now able to record its existence in the Falkland Islands area at WS 93 off West Falkland Island from a depth of 133 m. (TS 503/22), a record omitted from the Falkland Report owing to paucity of material. It also occurs at many Antarctic stations, at some of which the specimens are much larger and even more deserving of the name *tenuissima* than those from South Georgia.

157. **Textularia nitens**, sp.n. (Plate III, figs. 31–5).

Fifteen stations: 131, 144, 149; WS 33, 41, 42, 47, 63, 334, 343, 348, 373, 428, 429, 523.

Test very minute and fragile, compressed and leaf-shaped, consisting of five to seven pairs of chambers regularly increasing in size and breadth; early chambers compressed, later becoming slightly inflated; marginal edge rounded, slightly lobulate. Aperture a terminal slit parallel to face of test. Wall thin, constructed of minute sand grains, pale gold colour, glistening. Length up to 0·3 mm., breadth 0·13 mm., thickness 0·05 mm.

This delicate little species, though widely distributed in South Georgia, is very rare everywhere. Its range in depth is considerable (130–3705 m.), but it is most at home and usually attains its best proportions at the shallower stations. Single specimens of this species were noted at a depth of 161 m. at WS 210, to north of Falkland Islands, at WS 433, and at a depth of 1035 m. between the Falkland Islands and South Georgia. These stations were dealt with in the Falkland Report. The species occurs also at several Discovery stations in the Antarctic.

Genus **Bigenerina**, d'Orbigny, 1826

158. **Bigenerina minutissima**, sp.n. (Plate III, figs. 36–8).

Two stations: WS 199, 472.

Test very minute, rod-shaped, consisting of a large proloculum followed by three to four pairs of long narrow chambers increasing rapidly in size, but very little in width, ending with three cylindrical moniliform chambers and a terminal orifice. Sutures depressed. Constructed of small sand grains, rather large for the size of the organism, embedded in cement on a chitinous membrane. Colour pale brown. Length 0·35 mm., width 0·04 mm. Only a single specimen at WS 199 and a few at 472. The organism is so small that it might easily have been overlooked at other stations. Its structure is not easily seen, unless the specimens are mounted in balsam.

Genus **Verneuilina**, d'Orbigny, 1840

159. **Verneuilina advena**, Cushman (F 121) (Plate III, figs. 43–6).

Ten stations: 144, 149, 151, 660; WS 28, 32, 42, 47, 63–4, 373.

Common at St. 144, very rare elsewhere. The specimens are rather distinctive, being nearly always constructed of very minute micaceous particles embedded in the chitinous wall of the test. They are therefore more delicate and thin-walled than the finely arenaceous specimens so familiar in British gatherings, and the chambers appear to be more inflated owing to the thinness of the wall. But dimensions and number of chambers agree, and there appears to be no reason for separating the South Georgian specimens on account of their construction. Both long and short forms occur, as is usual in British gatherings also.

160. **Verneuilina bradyi**, Cushman.

Verneuilina pygmaea, Brady (*non* Egger), 1884, FC, p. 385, pl. xlvii, figs. 4–7.
Verneuilina pygmaea, Flint, 1899, RFA, p. 285, pl. xxxi, fig. 1.
Verneuilina bradyi, Cushman, 1910, etc., FNP, 1911, p. 54, fig. 87; 1918, etc., FAO, 1922, p. 59. pl. xi, fig. 1.

Eight stations: 53° 00′ S, 34° 22′ W; WS 334, 336, 353, 429, 521, 522, 523.

Confined to deep water at depths between 1697 and 4041 m. It is frequent at WS 429, 522 and 523, very rare elsewhere.

Genus **Gaudryina**, d'Orbigny, 1839

161. **Gaudryina bradyi**, Cushman.

Gaudryina pupoides, Brady (*non* d'Orbigny), 1884, FC, p. 378, pl. xlvi, figs. 1–4.
Gaudryina pupoides, Flint, 1899, RFA, p. 287, pl. xxxii, fig. 4.
Gaudryina bradyi, Cushman, 1910, etc., FNP, 1911, p. 67, fig. 107; 1918, etc., FAO, 1922, p. 74, pl. xii, fig. 8.

One station: WS 523.

Frequent well-grown specimens at a depth of 1697 m.

162. **Gaudryina flintii**, Cushman.

Gaudryina subrotundata, Flint (*non* Schwager), 1899, RFA, p. 287, pl. xxxiii, fig. 1.
Gaudryina flintii, Cushman, 1910, etc., FNP, 1911, p. 63, fig. 102; 1918, etc., FAO, 1922, p. 69, pl. xii, figs. 1, 2.

One station: WS 522.

A single large specimen at a depth of 2550 m.

163. **Gaudryina baccata**, Schwager.

Gaudryina baccata, Schwager, 1866, FKN, p. 200, pl. iv, figs. 12 *a*, *b*.
Gaudryina baccata, Brady, 1884, FC, p. 379, pl. xlvi, figs. 8–11.
Gaudryina baccata, Flint, 1899, RFA, p. 287, pl. xxxii, fig. 5.
Gaudryina baccata, Cushman, 1910, etc., FNP, 1911, p. 68, fig. 108.

One station: WS 521.

A single specimen.

164. **Gaudryina apicularis**, Cushman.

Gaudryina siphonella, Brady (*non* Reuss), 1884, FC, p. 382, pl. xlvi, figs. 17–19.
Gaudryina siphonella, Flint, 1899, RFA, p. 288, pl. xxxiv, fig. 2.
Gaudryina apicularis, Cushman, 1910, etc., FNP, 1911, p. 69, fig. 110; 1918, etc., FAO, 1922, p. 72, pl. viii, fig. 4.

One station: WS 353.

One perfect specimen and a broken one at this station at a depth of 4041 m.

Genus **Clavulina**, d'Orbigny, 1826

165. **Clavulina communis**, d'Orbigny (Plate III, figs. 39–42).

Clavulina communis, d'Orbigny, 1826, TMC, p. 268, no. 4; 1846, FFV, p. 196, pl. xii, figs. 1, 2.
Clavulina communis, Brady, 1884, FC, p. 394, pl. xlviii, figs. 1–13.
Clavulina communis, Cushman, 1918, etc., FAO, 1922, p. 84, pl. xvi, figs. 4, 5.

Nine stations: 53° 00′ S, 34° 22′ W; WS 199, 334, 336, 353, 365, 429, 521, 522.

Confined to the deep-water stations, the shallowest depth from which the species was recorded being 2549 m. at WS 429. Here the specimens were few and small, except for a fragment which must have belonged to a specimen far larger than any perfect one found. At WS 353 a large fragmentary specimen was obtained at a depth of 4041 m. The best specimens were from WS 199 and from a sounding of Diatom ooze taken in 53° 00′ S, 34° 22′ W (2472 m.). All the specimens except one were uniform in appearance, very smooth and neatly finished with fine grey mud, no coarse material being used. The exception occurred at WS 522, where of two specimens found, one was normal, the other very large and constructed of nearly black sand and cement. Young individuals, which have not grown beyond the triserial stage, occur at most stations. At WS 336 there were many of these, but no adult shells. Megalospheric specimens predominate everywhere.

Sub-family *BULIMININAE*

Genus **Bulimina**, d'Orbigny, 1826

166. **Bulimina fusiformis**, Williamson (F 124).

Four stations: 15, 129, 151; WS 18.

Common at St. 15, very rare elsewhere.

167. **Bulimina elegans**, d'Orbigny (F 127).

Five stations: 16, 136, 157; WS 37, 426.

Rare everywhere but well developed. Best and most numerous at St. 157 and WS 37.

168. **Bulimina marginata**, d'Orbigny (F 129).

Five stations: 20, 29, 149; WS 41, 47.

Only a single specimen at each station except at St. 149, where several were obtained. They are uniformly small and pauperate, except the specimen from St. 29, which is normal.

169. **Bulimina patagonica**, d'Orbigny (F 130).

Two stations: WS 349, 522.

Very rare and not very typical, the best at WS 522.

170. **Bulimina aculeata**, d'Orbigny (F 131).

Seven stations: 16, 149; WS 37, 63, 351, 429, 523.

Rare and extremely pauperate, except at WS 523, where a good many excellent specimens were found.

171. **Bulimina subteres**, Brady (F 134).

Three stations: 123, 144; WS 33.

Very rare and poorly developed at all stations.

172. **Bulimina elegantissima**, d'Orbigny (F 135) (Plate III, fig. 47).

One station: WS 27.

Represented in the South Georgian material by a single very fine "budding" specimen. In spite of the fact that WS 27 is off the west end of South Georgia, it is possible that this occurrence of only a single specimen of a typical Falkland species may be due to a foul net or sieve, rather than to an extension of habitat.

173. **Bulimina buchiana**, d'Orbigny.

Bulimina buchiana, d'Orbigny, 1846, FFV, p. 186, pl. xi, figs. 15–18.
Bulimina buchiana, Brady, 1884, FC, p. 407, pl. li, figs. 18, 19.
Bulimina buchiana, Cushman, 1918, etc., FAO, 1922, p. 95, pl. xx, fig. 4.

Four stations: WS 63, 429, 522; MS 14.

Rare or very rare. All the specimens are rather smaller than the average but otherwise typical; the largest and best were at WS 522.

Genus Virgulina, d'Orbigny, 1826

174. **Virgulina schreibersiana**, Czjzek (F 138).

Forty-five stations: 13, 14, 15, 20, 23, 28, 30, 31, 42, 45, 123, 129, 131, 136, 144, 145, 149, 151, 157, 660; WS 25, 27, 28, 32, 33, 37, 41, 42, 43, 45, 47, 50, 63–4, 113, 154, 348, 349, 351, 357, 418, 429, 522, 523; MS 14, 68.

Almost universally distributed and one of the most abundant species round South Georgia. It is common at most stations in the above list and very common at several, while at St. 144 and WS 63–4 it is a dominant form. By contrast there are stations (Sts. 15, 28, WS 28, 523) at which the species is extremely rare, and others (as at St. 30) where, though frequent, the specimens are pauperate and small. The best specimens were noted at MS 68, WS 25, 32, 33, 349 and 429. The variation referred to in the Falkland Report, viz. long and short forms usually occurring together, was noticed at most stations.

175. **Virgulina subsquamosa**, Egger (F 140).

Twelve stations: 20, 23, 28, 30, 136, 149; WS 25, 33, 40, 48, 349, 418.

Very rare and generally small and pauperate. The best specimens at WS 33 and 48.

176. **Virgulina bradyi**, Cushman (F 141).

Twenty-two stations: 15, 30, 45, 126, 136, 140, 144, 149, 660; WS 27, 32, 33, 40, 42, 48, 349, 357, 373, 429, 522, 523; MS 14.

Common at Sts. 144, 149, 660 and WS 42, elsewhere usually rare. There is considerable variety in the length as compared with the breadth of specimens at different stations. The best specimens were noted at Sts. 136, 144, 149, WS 32, 33, 373 and 523.

Genus **Bolivina**, d'Orbigny, 1839

177. **Bolivina punctata**, d'Orbigny (F 143).

Eighteen stations: 15, 16, 30, 45, 136, 143, 144, 149; WS 27, 32, 33, 47, 63–4, 113, 348, 429, 522; MS 14

Very rare and mostly represented by one or two specimens at each station except at St. 149, where it is very common. Some of the single specimens are very fine and typical; the majority are megalospheric.

178. **Bolivina textilarioides**, Reuss (F 144).

Two stations: 15; WS 33.

Very rare and pauperate.

179. **Bolivina robusta**, Brady (F 146).

One station: 149.

A few small and weak specimens only.

180. **Bolivina dilatata**, Reuss (F 148).

Two stations: 149; WS 47.

Extremely rare but very typical.

181. **Bolivina difformis** (Williamson) (F 149) (Plate III, figs. 50, 51).

Textularia variabilis var. *difformis*, Williamson, 1858, RFGB, p. 77, pl. vi, figs. 166, 167.
Bolivina difformis, Heron-Allen and Earland, 1913, CI, p. 65.
Bolivina difformis, Cushman, 1918, etc., FAO, 1922, p. 32, pl. iv, fig. 1.

One station: MS 14.

A single specimen, small, but typical.

182. **Bolivina malovensis**, Heron-Allen and Earland (F 153).

One station: WS 27.

This species, so abundant in the Falkland area, is represented by a few very weak individuals only, recorded with some hesitation.

183. **Bolivina cincta**, Heron-Allen and Earland (F 154).

Three stations: WS 351, 521, 522.

Rare, but typical and well developed.

Typical specimens of *B. cincta* occur frequently in the Challenger material from Challenger St. 300, to the north of Juan Fernandez Island in the Pacific (depth 1375 fathoms), so it is evident that the species has a wide distribution. It has some superficial resemblance to *Bolivina caelata*, Cushman (C. 1925, etc., LFR, v, p. 93, pl. xiii, fig. 28), but may be distinguished by its edge, which is broad and flat, whereas the edge of *B. caelata* is described as acute. No edge view of that species has been figured so far as I know.

184. **Bolivina decussata**, Brady (Plate III, figs. 48, 49).

Bolivina decussata, Brady, 1879, etc., RRC, 1881, p. 58; 1884, FC, p. 423, pl. liii, figs. 12, 13.
Bolivina decussata, J. Wright, 1891, SWI, p. 475.
Bolivina decussata, Cushman, 1910, etc., FNP, 1911, p. 47, fig. 77; 1918, etc., FAO, 1922, p. 32.

Two stations: WS 521, 522.

A single specimen at WS 521 and two at the other station, all quite typical. The records are of great interest as, with a single exception, the species has hitherto only been noted in the Pacific, viz. at Challenger Sts. 300 and 302 (1375 and 1450 fathoms respectively) both near Juan Fernandez Island, and at the Albatross St. 4839 off Japan (140 fathoms). The depth in the case of the Albatross specimens is remarkable as compared with the Challenger records and our own, which are from 3780 and 2550 m.

The only record outside the Pacific, so far, is of material from the south-west of Ireland, (50° 52′ N, 11° 27′ W) in which the species was noted by Joseph Wright to be "common at 1020 fathoms". In the absence of a figure it cannot be stated definitely what Wright's form was, and Cushman (1922, *ut supra*) states that he has found specimens in Wright's material which are evidently those referred to, but differing from the Pacific material he has seen. It is not clear whether he is referring to the Challenger types or to the material from Japan.

I have not found anything resembling *B. decussata* in Irish material, though I have dredgings from approximately the same locality as Wright.

In view of the present extension of the range of the species into the South Atlantic, there seems no inherent impossibility in Wright's record. It may be noted that the species shows a wide range of variation in the Challenger material.

Sub-family *CASSIDULININAE*

Genus **Cassidulina**, d'Orbigny, 1826

185. **Cassidulina laevigata**, d'Orbigny (F 157).

Three stations: WS 428, 521, 523.

Singularly rare, except at WS 428, where several specimens were observed.

186. **Cassidulina laevigata var. tumida, Heron-Allen and Earland.**

> *Cassidulina laevigata* var. *tumida*, Heron-Allen and Earland, 1922, TN, p. 137, pl. v, figs. 8–10.
> *Cassidulina laevigata* var. *tumida*, Cushman, 1925, LFR, 1, p. 54, pl. viii, figs. 40–2.

One station: WS 66.

Only a single and far from typical specimen. The variety was originally described from off Three Kings Islands, New Zealand (North Island) at a depth of 90–300 fathoms, but we have good specimens from a sounding made by the 'William Scoresby' off Gough Island (2000–3000 m.).

187. **Cassidulina pulchella, d'Orbigny (F 158).**

Two stations: WS 27, 521.

Extremely rare and very pauperate. Only a few specimens in all.

188. **Cassidulina crassa, d'Orbigny (F 160).**

Thirty-four stations: 20, 27, 30, 42, 45, 123, 126, 131, 136, 140, 143, 144, 148, 149, 660; WS 25, 27, 28, 31, 32, 33, 40, 42, 66, 113, 154, 314, 351, 418, 429, 521, 522, 523; MS 68.

The species, though widely distributed, does not occupy the dominant position which it assumes in the Falkland area and is very rare at many stations. All the forms met with in the Falkland area were found, but the large typical *crassa* is rare, and occurs only at Sts. 144, 148, 149, WS 27, 154 and 521, nearly always accompanied by the small hyaline form, which is the dominant type round South Georgia and is sometimes very common, especially at St. 144, WS 25, 27, 66 and 314. The intermediate type referred to in the Falkland Report also occurs at several stations, notably Sts. 123, 144 and WS 33. With increase of depth there is a marked tendency to decrease in size. Thus at WS 429 at a depth of 2549 m. the small type becomes quite minute, whereas at WS 522 and 523 at depths of 2550 and 1649 m. respectively the intermediate type is much reduced in size while acquiring a much thicker shell.

189. **Cassidulina subglobosa, Brady (F 162).**

Thirty-eight stations: 13, 20, 30, 31, 42, 123, 126, 131, 136, 140, 144, 149, 660; WS 25, 27, 28, 32, 33, 37, 40, 42, 43, 45, 47, 50, 51, 63–4, 66, 113, 154, 314, 348, 351, 418, 521, 522, 523; MS 68.

Very generally distributed but usually rare or very rare. It was, however, very common at St. 144, WS 33 and 66. As a rule the specimens are small and far from typical, the flattened form referred to in the Falkland Report occurring at many stations, sometimes exclusively. The best specimens of the typical form were seen at St. 149, WS 33, 522 and 523.

190. **Cassidulina parkeriana, Brady (F 163).**

Forty-five stations: 13, 14, 16, 20, 23, 27, 30, 31, 42, 45, 123, 126, 131, 136, 140, 144, 148, 149, 157; WS 25, 27, 28, 32, 33, 37, 40, 42, 43, 45, 46, 47, 48, 50, 52, 63, 66, 113, 154, 314, 348, 349, 357, 418, 426; MS 68.

This is the most generally distributed species of *Cassidulina*, but is seldom abundant except at a few stations, notably St. 23 where it is very common. It is common at Sts.

16, 20, 136, WS 27, 33, 48 and 418, elsewhere generally rare to very rare. Both megalospheric and microspheric specimens are found, wherever it is present in any numbers. Nowhere does it attain such size as in the Falkland area; the best specimens were at WS 33 and 42.

Genus Ehrenbergina, Reuss, 1850

191. **Ehrenbergina pupa** (d'Orbigny) (F 164).

Five stations: 30, 149; WS 25, 27, 33.

The extreme rarity of this species round South Georgia as compared with its abundance in the Falkland area is most marked, and points to the fact that it has not succeeded in establishing its footing in the colder water. It is moderately frequent at WS 27 which is off the north-west corner of the island and therefore on its line of approach from the Falkland area. At the remaining stations the species is represented by one or two specimens only.

192. **Ehrenbergina hystrix** var. **glabra**, Heron-Allen and Earland (F 165).

Five stations: WS 33, 51, 66, 314, 418.

This Antarctic form is common at WS 51, but the specimens are rather small though typical. At all the other stations it is very rare, but the few specimens found were generally large, though often weakly developed as regards the marginal spines.

193. **Ehrenbergina crassa**, Heron-Allen and Earland (Plate VI, figs. 1–9).

Ehrenbergina crassa, Heron-Allen and Earland, 1929, etc., FSA, 1929, p. 329, pl. iii, figs. 18–26.

Fifty stations: 13, 14, 20, 23, 27, 28, 30, 31, 41, 42, 45, 123, 126, 131, 136, 140, 143, 144, 148, 149, 157, 660; WS 20, 25, 27, 28, 32, 33, 37, 40, 41, 42, 43, 45, 46, 47, 48, 50, 51, 52, 66, 113, 154, 314, 348, 349, 357, 418; MS 14, 68.

Test very thick-walled throughout, finely perforate, hyaline in the younger stages, but frequently becoming white and semi-opaque in the adult shell. Constructed of a variable number of chambers regularly increasing in size, arranged biserially about an elongate axis and presenting well-marked dorsal and ventral sides. The main axis of the shell is normally straight, but occasionally exhibits a spiral tendency, thus giving a virguline appearance to such tests. The dorsal side of the test is flatter and wider than the ventral, and the sutural lines, which are depressed, are more prominent on the dorsal side owing to their greater thickness.

The sutures are most noticeable in the oral half of the shell, those of the initial half being usually more or less obscured by a secondary layer of shell substance which is sometimes granular or even feebly striated. The oral half of the shell is quite smooth and devoid of ornament. The aperture is a loop-like slit set obliquely on the inner face of the final chamber.

The initial portion of the shell consists of a more or less prominent knob, curved over towards the ventral side and excentric to the main axis of the shell. In the megalospheric form, this knob is very prominent, and contains the proloculum situated on its ventral face, behind which is the first pair of chambers. In the microspheric form, it contains the proloculum followed by one plano-spiral convolution of minute biserial chambers regularly increasing in size, the axis of the spiral being at right angles to the main axis of the shell.

The megalospheric form predominates everywhere, sometimes to the entire exclusion of the microspheric. Its appearance is very distinctive, especially in young specimens, where the proloculum shows like a glassy bubble on the ventral side of the bulbous top. As the shell develops, it becomes less noticeable owing to the deposition of secondary shell matter. The pair of chambers immediately following the proloculum are compressed in shape, owing to their position on the dorsal side behind the proloculum. After them the chambers are regularly arranged biserially. Average specimens exhibit four to five pairs of chambers, but several specimens having as many as seven to eight pairs have been seen.

The microspheric form is easily distinguished by its narrower initial end, which is rather wedge-shaped than bulbous. Owing to the thickness of the wall, the internal structure is difficult to determine, but, as previously stated, the very small proloculum is followed by a plano-spiral coil of minute biserial chambers (probably four to five pairs), regularly increasing in size, and followed by a further series of six to eight pairs of straight chambers. The microspheric form thus attains a greater average length than the megalospheric, the other dimensions remaining much the same.

An average megalospheric specimen measures about 0·70 mm. in length by 0·30 mm. in greatest breadth and 0·25 mm. in thickness. One very large specimen attained 1·08 mm. in length. The megalosphere as measured in optical section (internal) averages 0·1 mm. in diameter.

Microspheric specimens average about 0·90 mm. in length by 0·35 mm. in greatest width and 0·30 mm. in thickness. A large specimen attained 1·35 mm. in length. The microsphere could not be measured with any certainty, owing to the thickness of the shell. It is certainly very minute.

E. crassa is a very abnormal type, and until its relationships were definitely established by the discovery of the microspheric form with its coiled initial portion, its systematic position remained uncertain. Its nearest ally is unquestionably *E. pupa* (d'Orbigny), from which it differs in many points, notably in the marked development of the produced series of chambers and their regular Bolivine arrangement. *E. pupa* was first described by d'Orbigny from the Falkland Islands, and it is one of the most abundant and variable species in the Discovery collections from that area. None of the variations, however, approaches *E. crassa*, which does not occur at all in the Falkland area, but is relatively common in South Georgia and adjacent waters, and, so far as our present knowledge goes, is almost confined to that area, where it constitutes one of the most characteristic local species. Presumably the two species, *E. pupa* and *E. crassa*, are derivatives from a common ancestor which inhabited both areas.

I have little to add to the information already published and quoted above. *E. crassa* is certainly the most typical if not the commonest species round South Georgia, occurring in greater or less abundance at more than half of all the stations examined.

The depths range between 18 and 346 m., the latter depth being at WS 28, where the species is frequent and well developed. This range has only been extended by the finding of a single fragmentary specimen at St. 157 in 970 m., to which we should not attach any importance as its presence may be accidental. The species is most at home in shallower water, the best stations being Sts. 30, 45, 123, 126, 149, 660, WS 25, 42 and 154, with an average depth of about 190 m. Megalospheric and microspheric forms were found together at twenty-five stations, including the nine just mentioned. At the other stations megalospheric individuals only were observed. There appears to be great range in the size of the megalospheric proloculum; exceptionally large primordial chambers were seen in specimens obtained from St. 27 and WS 66.

The texture of the shell is normally smooth and glossy, becoming smooth but dull with age. After death the secondary deposit of shell substance appears to disintegrate rather quickly, leaving a roughened surface. This is quite distinct from a superficial roughening due to the formation of minute beads or spines or striae, a variation which appears to be rather rare, having been observed only at MS 68, WS 25, 27, 33, 37, 66 and 349. At MS 68 nearly all the specimens were coated with a thin layer of fine mud, so that the nature could only be guessed at from the characteristic shape of the mud lumps. The coating was readily dislodged and its nature is obscure; it appears to be too thin to be regarded as encystment.

194. **Ehrenbergina bradyi**, Cushman (F 166).

Two stations: WS 521, 522.

A few small individuals at WS 521 and 522. Both the stations are in deep water.

Family CHILOSTOMELLIDAE

Genus **Seabrookia**, Brady, 1890

195. **Seabrookia earlandi**, J. Wright (F 168).

One station: WS 429.

Rare, but a good many specimens were found at this station at a depth of 2549 m.

Family LAGENIDAE

Sub-family *LAGENINAE*

Genus **Lagena**, Walker and Boys, 1784

Owing to the number of species recorded, they have been placed in alphabetical order for facility of reference.

196. **Lagena acuta** (Reuss) (F 211).

Eighteen stations: 20, 30, 126, 144, 149; WS 25, 28, 33, 42, 46, 48, 63–4, 66, 113, 154, 349, 521; MS 14.

Widely distributed, but less frequent than *L. biancae*, into which it merges imperceptibly, presenting similar variations in the degree of compression and length of test. The spinous base is very poorly developed everywhere, except at WS 521, where it is prominent. At this station and at WS 154 the species is most favourably represented. At most stations the specimens are small, few in number and very near *L. biancae*, the basal process being more or less rudimentary.

197. **Lagena acuticosta**, Reuss (F 196) (Plate III, fig. 52).

Six stations: 27, 33, 123; WS 27, 33, 418.

Usually only a single typical specimen at each station. At St. 33 a very fine example of a double shell was found. The individuals, which are large, are as usual fixed apex to base.

198. **Lagena alveolata, var. substriata**, Brady.

Lagena auriculata var. *substriata*, Brady, 1879, etc., RRC, 1881, p. 61.
Lagena alveolata var. *substriata*, Brady, 1884, FC, p. 488, pl. lx, fig. 34.
Lagena alveolata var. *substriata*, Cushman, 1910, etc., FNP, 1913, p. 34, pl. xviii, fig. 5.

One station: WS 522.

A single good specimen.

199. **Lagena annectens**, Burrows and Holland (F 215).

Seven stations: 30, 144, 149; WS 27, 33, 50; MS 14.

Never very common, usually very feeble specimens, the best at St. 149 and WS 33.

200. **Lagena apiculata** (Reuss) (F 174) (Plate IV, figs. 1–3).

Twenty-three stations: 13, 42, 45, 131, 660; WS 32, 33, 37, 40, 42, 43, 46, 47, 48, 50, 52, 63, 113, 154, 314, 349, 357, 522.

This is one of the most widely distributed species in the South Georgian material, and though never common, some stations yielded many specimens, which often exhibited variety of form. The average specimen is of a small regular type, but the aperture is variable. Usually radial and central, the aperture is sometimes radial but excentric, sometimes fissurine, and at WS 349 fissurine and hooded.

A very large form compared with the others occurs at many stations. It is characterized by a long, regularly tapering shell ranging up to 0·7 mm. in length, broadest towards the base which is furnished either with a small circular pit or a short projecting tube. The pit or tube may be pierced so as to form a secondary aperture but is usually closed. The aperture is prominent and radial. This form is the sole representative of the species at Sts. 42, 131, 660, WS 43, 46, 48, 50, 52, 154 and 357. At some other stations it is accompanied by other varieties. At St. 131, WS 42, 46 and 50, a few specimens had basal striae radiating from the tube. I was at first inclined to assign the specimens to *L. stelligera*, but on the whole the evidence points to *L. apiculata*.

201. **Lagena auriculata**, Brady (F 245).

Two stations: WS 63, 521.

Only a single specimen at each station, quite typical.

202. **Lagena biancae** (Seguenza) (F 210).

Twenty-two stations: 15, 17, 27, 123, 126, 136, 144, 145, 149; WS 25, 27, 33, 37, 42, 43, 47, 48, 418, 429, 521, 522; MS 68.

Probably the most common species of *Lagena* round South Georgia, though never so abundant as in some of the Falkland gatherings, or presenting such a range of variation. Most abundant and varied at WS 27 and 33, where fine and typical specimens were found, also the strongly punctate form. Neither of these, however, were so abundant here or elsewhere as a small rather globose form which is the commonest variety at most stations and is frequently the sole representative of the species. The type was found at Sts. 27, 126, 136, 144, WS 27, 33 and 418. At WS 429 and 521, single specimens of a very elongate fissurine variety were found.

203. **Lagena bicarinata** (Terquem) (F 236).

Three stations: WS 25, 33, 373.

Extremely rare; a single specimen only at each station, the best being at WS 373.

204. **Lagena bisulcata**, Heron-Allen and Earland (F 239).

Six stations: 136; WS 25, 27, 33, 357, 418.

Good and typical specimens were not infrequent at the few stations at which the species was observed, except at WS 27 and 33, where it was very rare. They are all of a coarse, thick-walled form except at WS 27, where the single specimen was small and weak. The species was most abundant and most strongly developed at WS 357.

205. **Lagena catenulata**, Reuss (F 201).

Five stations: WS 27, 33, 42, 521, 522.

Rare. With the exception of very strongly marked specimens at WS 521 and 522, all the specimens are far from typical, the cross-bars being almost absent over much of the basal half of the test. They are thus intermediate between *L. catenulata* and *L. squamoso-sulcata*, Heron-Allen and Earland (No. 244).

206. **Lagena clathrata**, Brady (F 243).

One station: WS 429.

A single specimen from WS 429 is probably referable to Brady's species, though very unlike the usual types. It is elongate, broadest near the base, which is furnished with a supplementary tubular aperture. Of the three marginal keels, the mid-keel is less prominent than the outer two, except in the oral region where it extends beyond them. The faces of the shell are finely striate.

Sidebottom figures a somewhat similar specimen (S. 1912, etc., LSP, 1913, p. 196 pl. xvii, fig. 14) from the South-west Pacific, under the name *L. orbignyana* var. *clathrata*. His figure, however, has only three costae on the face, as against many in ours, and is devoid of the basal aperture.

207. **Lagena costata** (Williamson) (F 195).

Three stations: WS 27, 429, 521.

Only a few specimens, those at WS 27 being characterized by numerous fine costae, while at the other stations the costae are few but prominent.

208. **Lagena danica**, Madsen (F 234).

Two stations: WS 33, 48.

Single small specimens only.

209. **Lagena distoma**, Parker and Jones (F 186).

Two stations: 144; WS 32.

Very rare, two specimens only at St. 144, and one at WS 32, all small and feebly striate.

210. **Lagena fasciata** (Egger) (F 212).

Two stations: WS 25, 32.

A few feeble examples at each station.

211. **Lagena fasciata var. faba**, Balkwill and Millett (F 213).

One station: WS 522.

A single specimen.

212. **Lagena felsinea**, Fornasini (Plate IV, figs. 4, 5).

Lagena emaciata var. *felsinea*, Fornasini, 1901, NNI, p. 47, fig. 1.
Lagena felsinea, Cushman, 1910, etc., FNP, 1913, p. 10, pl. iv, fig. 1; 1918, etc., FAO, 1923, p. 17.

Three stations: 144; WS 42; MS 68.

Several specimens at St. 144, single ones only at the other stations.

213. **Lagena fimbriata**, Brady (F 232).

Seven stations: 45, 136, 144; WS 33, 40, 42, 351.

A single typical example only at WS 351, resembling one of Brady's figures (B. 1884, FC, pl. lx, fig. 26). Otherwise the species is represented round South Georgia only by a minute variety in which the basal wings are reduced to a minimum, often represented only by an opaque white line curving round each side of the base. A few specimens of this form at each station.

214. **Lagena formosa**, Schwager.

Lagena formosa, Schwager, 1866, FKN, p. 206, pl. iv, figs. 19 *a–d*; pl. vii, fig. 1.
Lagena formosa, Brady, 1884, FC, p. 480, p. lx, figs. 10, 18–20.
Lagena formosa, Millett, 1898, etc., FM, 1901, p. 624, pl. xiv, figs. 10–12.
Lagena formosa, Cushman, 1910, etc., FNP, 1913, p. 41, pl. xi, fig. 6.

Three stations: WS 33, 521, 522.

A single very fine specimen at WS 33 and 521, and a small one at WS 522.

215. **Lagena formosa**, Schwager, var.n. **costata** (Plate IV, figs. 16–18).

One station: WS 522.

At this station a few specimens of a very distinctive variety were found. The test is rather small and generally presents all the characteristics of the species, but the faces of the shell are ornamented centrally with a few straight costae, four to six in number. These occupy only the centre of the face and do not extend to the raised edge as in the well-known variety *comata*, Brady. The wing is rather broad and coarsely tubulated and the basal cleft very distinct.

There is some variation in the relative dimensions of specimens, two of which were respectively 0·35 and 0·40 mm. long and 0·22 and 0·20 mm. broad.

216. **Lagena foveolata**, Reuss (F 204).

Two stations: 126; WS 429.

Extremely rare. The single specimen found at St. 126 is very weak, but at WS 429 two specimens were found which, although very small, are most typical in their markings.

217. **Lagena globosa** (Montagu) (F 169).

Eight stations: 16; WS 25, 32, 33, 66, 314, 521, 523.

Very rare, seldom more than one or two specimens at each station. The best station is WS 33, where the species occurs typical and large. A compressed variety also occurs with the type at this station and at WS 521. At St. 16 the compressed variety only occurs.

218. **Lagena gracilis**, Williamson (F 185).

Eight stations: 45; WS 37, 45, 47, 113, 429, 521, 522.

Rare except at WS 37, where a good many typical specimens were obtained. There is the usual wide range of variation in the strength of the markings, which are very feeble at some stations. Those from WS 521 are extremely coarse. At WS 522 there is a series with costae ranging from feeble to very coarse.

219. **Lagena gracillima** (Seguenza) (F 177).

Fourteen stations: 14, 20, 42, 45, 131, 136, 144; WS 33, 37, 42, 50, 154, 349, 357.

Rare and represented by one or two specimens only at most of the stations. More abundant at St. 131. All the specimens are well developed. Two forms occur, the typical straight form of Seguenza and a curved variety which is well illustrated by Brady (B. 1884, FC, pl. lvi, fig. 24). The two forms occur together at Sts. 42 and 144, the curved variety only at St. 45, WS 33, 42, 50 and 154, and only the typical straight form, which sometimes reaches large dimensions, at all the remaining stations.

220. **Lagena hartiana**, sp.n. (Plate IV, figs. 12, 13).

One station: WS 522.

Test minute, hyaline, compressed, broadest and thickest at a point about three-quarters of the length of the shell from the aperture, which is fissurine and situated on a slightly thickened and produced collar. In edge-view it shows five narrow carinae, the central and outer carinae projecting beyond the intermediates. The face of the test is covered with longitudinal costae, five in number, converging towards the extremities of the test. The facial costae are of about the same strength as the intermediate carinae. Length 0·25 mm., breadth 0·1 mm.

This is rather a striking little form without any very definite affinities. It may be compared with a figure assigned by Sidebottom to *L. orbignyana* var. *clathrata*, Brady (S. 1912, etc. LSP, 1913, p. 196, pl. xvii, fig. 14), but his specimen though agreeing in general construction has only three marginal carinae and three costae running down each face. Its assignment to *L. clathrata* seems rather far-fetched, but it is evidently closely allied to my species.

This species is named after T. J. Hart, B.Sc., of the Discovery staff.

221. **Lagena herdmani**, sp.n. (Plate IV, figs. 10, 11).

One station: WS 523.

Test minute, hyaline, compressed, consisting of a flask-shaped body with a produced neck. The flask has two narrow thickened carinae, whitish in colour owing to the presence of numerous tubuli. The carinae merge at the oral end of the flask into a tapering untubulated wing, which extends up the sides of the neck. This neck is almost as long as the flask and is continued as an entosolenian tube into the flask. The faces of the flask are convex and the carinae are separated at the edges of the test by a broad space showing no trace of a median keel. Length 0·22 mm., breadth 0·09 mm.

This rather distinctive little form combines the tubulations of *L. lagenoides* with the untubulated double carinae of *L. bicarinata*, and appears to be undescribed, although there are several records closely resembling it, but differing in essential points (compare S. 1912, LSP, etc., 1912, p. 414, pl. xix, fig. 9, a description of a variety of *L. formosa*). His figure closely resembles my species except for its apiculate base and median carina. Sidebottom states, however, that "in a few cases the wing or keel dies away almost as soon as it reaches the body of the test". This variation would be practically identical with my form but could no longer be ranked with *L. formosa*.

Another figure deserving of reference is that of *L. lagenoides*, Sidebottom (S. *ut* *supra*, p. 413, pl. xix, fig. 3), differing in the absence of a produced neck and the broader and more coarsely tubulated carinae.

This species is named after H. F. P. Herdman, M.Sc., of the Discovery staff.

222. **Lagena hexagona** (Williamson) (F 202).

Eight stations: 27, 31, 131; WS 27, 33, 42, 154, 522.

Never very frequent but good and typical specimens, especially at St. 131 and WS 154. The single specimen at WS 522 has exceptionally large and coarse markings.

223. **Lagena hispidula**, Cushman (F 180).

Four stations: 123; WS 33, 429, 522.

Single specimens at St. 123, WS 33 and 522. Many smaller but very typical examples at WS 429.

224. **Lagena laevis** (Montagu) (F 179).

Seven stations: 129, 149; WS 37, 50, 66, 429, 521.

Rare, most of the specimens being small and narrow. At WS 66 a single curious specimen occurred, characterized by a thick glassy shell with a milk-white annulus encircling the test near the base.

225. **Lagena lagenoides** (Williamson) (F 226).

Two stations: 144; WS 522.

At St. 144 a single specimen only occurred, agreeing with Williamson's type figures, and one of a large deep-water type at WS 522.

226. **Lagena lagenoides var. tenuistriata**, Brady (F 228).

Two stations: WS 429, 522.

A single very fine specimen at each station.

227. **Lagena lineata** (Williamson) (F 183).

Six stations: 123, 144; WS 25, 33, 429, 522.

Rarely more than a single specimen at a station and all very feebly marked. The usual form is almost globular with a broad oral end, but Williamson's typical oval form also occurs more sparingly. Both varieties are found at WS 33, where the species occurs more frequently than at any other station.

228. **Lagena lucida** (Williamson) (F 214).

Two stations: 144; WS 33.

Only a few specimens at each station, the best developed at WS 33.

229. **Lagena lyellii** (Seguenza) (F 190).

Two stations: 20, 149.

A single weakly marked specimen at each station.

230. **Lagena mackintoshiana**, sp.n. (Plate IV, figs. 14, 15).

Two stations: WS 27, 33.

Test pear-shaped with a produced and regularly tapering neck. From a small basal ring some 10–12 very feeble flattened costae radiate and extend to the base of the neck where they coalesce. These costae, which are so slightly elevated above the body of the shell as to be visible only with very oblique illumination, are decorated with a chain of depressed pits. The surface between the costae is covered with similar pits less regularly arranged. Length 0·6 mm., breadth 0·3 mm.

Only a few specimens, all but one in a poor state of preservation. It is possible that in the perfect condition the whole of the ornament is enclosed by an outer pellicle or skin, as in *L. scottii*, Heron-Allen and Earland (H.-A. and E. 1922, TN, p. 150, pl. vi, figs. 3–4).

Apart from this conjecture the affinities of the species appear to lie near *L. torquata*, Brady (B. 1884, FC, p. 469, pl. lviii, fig. 41).

This species is named after Dr N. A. Mackintosh of the Discovery staff.

231. **Lagena macroptera** (Seguenza) (Plate IV, figs. 6, 7).

Fissurina macroptera, Seguenza, 1862, FMMM, p. 70, pl. ii, fig. 44.

One station: WS 429.

The single specimen which we figure appears to agree sufficiently well with Seguenza's description and illustration to justify the revival of a name which has apparently never been used by any subsequent author. In the specimen from South Georgia the keel is somewhat narrower and the test more compressed than the original figure would suggest. Length 0·25 mm., breadth 0·13 mm.

The species appears to have affinities with *L. marginata*. Sidebottom (S. 1912, etc., LSP, 1912, p. 406, pl. xvii, fig. 29) figures a very similar form under that name, but his figure does not suggest the hyaline texture of our specimen. It cannot be confused with *L. marginata* var. *semimarginata*, Reuss, in which the carina is confined to the oral extremity of the shell round the produced neck.

232. **Lagena marginata** (Walker and Boys) (F 221).

Fifteen stations: 123, 144, 149; WS 25, 27, 33, 37, 48, 66, 314, 357, 418, 429, 521, 522.

Never very common, often represented by one or two specimens only. Not a single specimen with a fully developed carina was seen, the usual type being a somewhat globose fissurine form with only a suggestion of a keel.

At a few stations the carina is better developed, a feature apparently accompanied by a flattening of the test. The most highly carinate individuals were seen at WS 25, 33, 418 and 429, but the carina is always feebly developed.

233. **Lagena marginata var. quadricarinata**, Sidebottom (Plate IV, fig. 41).

Lagena staphyllearia var. *quadricarinata*, Sidebottom, 1912, etc., LSP, 1912, p. 404, pl. xxi, fig. 16.

One station: WS 522.

A single specimen 0·20 mm. in width occurred, differing from Sidebottom's figure only in the absence of the few basal spines and the lesser development of the principal carina. It may be observed that no mention of these spines is made in the text, although they are presumably responsible for the assignment of the form to *L. staphyllearia.* But they appear to bear no relationship to the marginal spines of that species, and both Sidebottom's figure and my own specimen would appear to be more nearly related to *L. marginata.*

234. **Lagena marginata var. striolata**, Sidebottom.

Lagena marginata var. *striolata*, Sidebottom, 1912, etc., LSP, 1912, p. 408, pl. 18, figs. 10, 11.

One station: WS 522.

Two specimens only were found. They resemble the finely striate specimen (fig. 10) figured by Sidebottom, but the markings are much more delicate. Though very distinct over the base and edges of the flask, they become indistinct over the central and upper half, appearing more as hair-streaks than as definite striae. There is no basal cleft as in Sidebottom's figure, the carina being continuous round the base.

235. **Lagena melo** (d'Orbigny) (F 200).

One station: WS 33.

A single, rather weak specimen at WS 33.

236. **Lagena orbignyana** (Seguenza) (F 240).

Five stations: 15; WS 33, 37, 42, 314.

Never more than a few specimens at a station, very good and typical specimens of the nearly circular form at WS 33 and 314. At WS 37 and 42 a small variety occurs with the central carina abnormally developed in the basal half and all three carinae partly suppressed in the oral half of the shell.

237. **Lagena quadralata**, Brady (F 230).

Two stations: 136; WS 33.

A single specimen at St. 136 and four at WS 33. They are all fine examples of the many-winged form described by us from the Falkland area.

238. **Lagena quadrata** (Williamson) (F 218).

One station: WS 521.

A single good specimen.

239. **Lagena reticulata** (Macgillivray) (F 199).

One station: WS 25.

A single good specimen.

240. **Lagena revertens**, Heron-Allen and Earland (F 238).

Two stations: WS 27, 418.

A single typical specimen at WS 27 and a feeble and broken shell at WS 418.

241. **Lagena schlichti** (A. Silvestri) (F 225).

Four stations: 136; WS 27, 33, 522.

One very fine specimen at St. 136, others not so good at WS 522, and doubtful specimens at the other stations.

242. **Lagena spumosa**, Millett (F 205).

Three stations: 16; WS 43, 46.

A single specimen at each station, particularly fine and typical at WS 46.

243. **Lagena squamosa** (Montagu) (F 197).

Four stations: 131; WS 25, 33, 349.

Singularly rare, represented by one or two specimens only at each station, the best at St. 131. One specimen at WS 33 might have been attributed to *L. squamoso-sulcata*, but as the squamous markings covered quite three-quarters of the test it was referred to *L. squamosa*.

244. **Lagena squamoso-sulcata**, Heron-Allen and Earland (F 196 A).

One station: WS 33.

Only a single typical specimen.

245. **Lagena staphyllearia** (Schwager) (F 224).

One station: WS 33.

A few small but typical specimens.

246. **Lagena stewartii**, J. Wright (F 171).

Two stations: WS 27, 33.

A single specimen at each station, particularly typical at WS 33.

247. **Lagena striata** (d'Orbigny) (F 188).

Nine stations: 16, 20, 129, 144; WS 25, 33, 37, 48, 349.

Good and well-marked shells occur, usually as single specimens, except at WS 33 and 37, where the species is more abundant. They are all of the elongate type first figured by Williamson.

248. **Lagena sulcata** (Walker and Jacob) (F 189).

Five stations: 149; WS 27, 33, 429, 522.

Extremely rare, a single specimen only at each station, and with the exception of WS 429 and 522 all very feebly sulcate.

249. **Lagena ventricosa**, A. Silvestri (Plate IV, figs. 8, 9).

Lagena ventricosa, Silvestri, 1903, PMP, p. 10, figs. 6 *a–c*.
Lagena globosa, Sidebottom, 1912, etc., LSP, 1912, p. 379, pl. xiv, figs. 4, 5.
Ellipsolagena, gen.n., Silvestri, 1923, SE, p. 265.
Ellipsolagena ventricosa, Cushman, 1928, F, p. 265, pl. xxxviii, fig. 10.

One station: WS 522.

Two specimens only with well-developed hoods. One specimen is decidedly compressed, resembling Sidebottom's fig. 5 (*ut supra*).

250. **Lagena williamsoni** (Alcock) (F 192).

Three stations: WS 25, 429, 522.

A single feeble specimen of the English type at WS 25, and strongly costate individuals at WS 429 and 522.

Sub-family *NODOSARIINAE*

Genus **Nodosaria**, Lamarck, 1812

251. **Nodosaria rotundata** (Reuss) (F 247).

One station: WS 349.

A single large specimen only.

252. **Nodosaria laevigata**, d'Orbigny (F 248).

One station: WS 523.

Recognizable fragments of a large specimen at this station constitute the only record for this species.

253. **Nodosaria scalaris** (Batsch) (F 250).

Two stations: 149; WS 349.

Very rare, but several good and typical specimens at St. 149.

254. **Nodosaria calomorpha**, Reuss (F 252) (Plate IV, fig. 19).

Four stations: 144; WS 33, 47, 429.

Very rare but very fine specimens ranging up to the exceptional number of 6–9 chambers at St. 144 and WS 33. At the other stations the specimens are of the normal minute type with 2–3 chambers.

255. **Nodosaria consobrina**, d'Orbigny.

Dentalina consobrina, d'Orbigny, 1846, FFV, p. 46, pl. ii, figs. 1–3.
Nodosaria consobrina, Brady, 1884, FC, p. 501, pl. lxii, figs. 23, 24.
Nodosaria consobrina, Halkyard, 1919, BMB, p. 67, pl. iv, fig. 7.

Three stations: 45, 144; WS 33.

Rare, but several excellent specimens were found at St. 45.

256. **Nodosaria communis**, d'Orbigny (F 254).

One station: WS 522.

A single very small specimen.

257. **Nodosaria pauperata** (d'Orbigny) (F 255).

Two stations: 136, 144.

The species is poorly represented by a fragment of a large individual at St. 136, and one three-chambered specimen at St. 144.

Genus **Lingulina**, d'Orbigny, 1826

258. **Lingulina vitrea**, Heron-Allen and Earland (F 264).

One station: WS 33.

One specimen only, not very typical, being thicker than the Falkland types.

Genus **Vaginulina** d'Orbigny 1826

259. **Vaginulina legumen** (Linné) (F 265).

One station: WS 429.

A small specimen only.

260. **Vaginulina linearis** (Montagu).

Nautilus linearis, Montagu, 1803–8, TB, Suppl. p. 87, pl. xxx, fig. 9.
Vaginulina linearis, Brady, 1884, FC, p. 532, pl. lxvii, figs. 10, 12.
Vaginulina linearis, Goës, 1894, ASF, p. 66, pl. xii, fig. 664.

One station: WS 521.

Represented by a single immature specimen, consisting of a megalospheric proloculum and one subsequent chamber.

Genus **Marginulina**, d'Orbigny, 1826

261. **Marginulina glabra**, d'Orbigny.

Marginulina glabra, d'Orbigny, 1826, TMC, p. 259, No. 6, Modèle no. 55.
Marginulina glabra, Brady, 1884, FC, p. 527, pl. lxv, figs. 5, 6.
Marginulina glabra, Cushman, 1918, etc., FAO, 1923, p. 127, pl. xxxvi, figs. 5, 6.

Two stations: WS 429, 523.

A single good specimen at each station at depths of 2549 and 1697 m. respectively.

Genus **Cristellaria**, Lamarck, 1812

262. **Cristellaria crepidula** (Fichtel and Moll) (F 268).

One station: WS 418.

Only a single very small specimen. The absence of this species at other stations is quite extraordinary.

263. **Cristellaria gibba**, d'Orbigny (F 274).

Two stations: WS 522, 523.

Extremely rare and small, the best specimen at WS 523.

264. **Cristellaria cultrata** (Montfort) (F 278).

One station: WS 522.

A single small specimen.

265. **Cristellaria convergens**, Bornemann (F 281).

One station: WS 418.

A single small specimen only.

Sub-family *POLYMORPHININAE*

Polymorphina, d'Orbigny, 1826

266. **Polymorphina lactea** (Walker and Jacob) (F 283).

One station: WS 521.

The aboral half of a large specimen was found at WS 521; it is worthy of record only on account of the depth (3780 m.) at this station which lies in the deep water between the Falkland Islands and South Georgia. The species is normally of shallow water habitat, but Brady records "exceedingly small" specimens at 1990 fathoms in the South Atlantic and at 2350 fathoms in the South Pacific.

267. **Polymorphina williamsoni**, Terquem (F 285).

One station: WS 314.

A single specimen only.

268. **Polymorphina compressa**, d'Orbigny (F 292).

Three stations: 149; MS 14; WS 33.

A few very minute and pauperate specimens are with some hesitation referred to this species.

Genus **Uvigerina**, d'Orbigny, 1826

269. **Uvigerina canariensis**, d'Orbigny (F 294).

One station: WS 429.

A single poor specimen.

270. **Uvigerina pygmaea, d'Orbigny (F 297).**

Two stations: WS 33, 349.

Very rare and weakly developed.

271. **Uvigerina aculeata, d'Orbigny.**

Uvigerina aculeata, d'Orbigny, 1846, FFV, p. 191, pl. xi, figs. 27, 28.
Uvigerina aculeata, Brady, 1884, FC, p. 578, pl. lxxv, figs. 1–3.
Uvigerina aculeata, Cushman, 1910, etc., FNP, 1913, p. 100, pl. xliii, fig. 4.

Two stations: WS 429, 522.

Rare at WS 522, but very good specimens. Very rare and weaker at the other station.

272. **Uvigerina raricosta, d'Orbigny (F 299).**

One station: WS 521.

Only a single specimen was noted, but it is possible that the species having no very striking characteristics has been overlooked elsewhere among the variations of *U. angulosa*.

273. **Uvigerina striata, d'Orbigny (F 300).**

Nine stations: 123; WS 27, 33, 50, 66, 314, 349, 418, 521.

Extremely rare. Never more than one or two specimens at a station.

274. **Uvigerina angulosa, Williamson (F 301).**

Forty-one stations: 13, 16, 23, 27, 28, 30, 45, 123, 126, 131, 136, 140, 144, 149, 157; WS 25, 27, 28, 33, 37, 40, 42, 43, 50, 51, 52, 66, 113, 154, 314, 348, 349, 351, 357, 373, 418, 426, 428, 521, 522, 523.

Generally distributed, but by contrast with the Falkland area the species is very rare at the majority of stations. It is, however, common or very common at St. 136, WS 66, 314, 357 and 418, and at these stations practically all the variations referred to in the Falkland Report were observed, notably at WS 357.

275. **Uvigerina angulosa var. spinipes, Brady.**

Uvigerina spinipes, Brady, 1879, etc., RRC, 1881, p. 64.
Uvigerina angulosa, var. *spinipes*, Brady, 1884, FC, p. 577, pl. lxxiv, figs. 19, 20.
Uvigerina angulosa, var. *spinipes*, Cushman, 1910, etc., FNP, 1913, p. 99, pl. xliii, fig. 3.

One station: WS 351.

Extremely rare, represented by a few specimens only.

Family GLOBIGERINIDAE

Genus **Globigerina**, d'Orbigny, 1826

NOTE. At WS 522 at a depth of 2550 m. a few specimens were observed of *G. inflata*, *G. pachyderma* and *G. dutertrei*. What are apparently the parent shells have smaller individuals firmly attached, usually to the last chamber of their tests (see Plate IV, figs. 20–22). They might be regarded merely as monstrosities, but for the fact that similar specimens have been observed more frequently in some of the Antarctic material, sometimes bearing more than one accessory shell. Their presence is not easily explained unless they are young specimens, discharged or budding from a parent shell, which have failed to attain separate existence. Compare the note on *Haplophragmoides canariensis* (No. 109). They are quite different from the "wild growing monstrous forms" figured by Brady (B. 1884, FC, p. 593, pl. lxxxi, figs. 6, 7), which appear to be due to fusion of fully grown individuals.

276. **Globigerina bulloides**, d'Orbigny (F 304).

Twenty-seven stations: 27, 30, 123, 131, 133, 138, 144, 149; WS 20, 25, 27, 28, 32, 33, 36, 40, 42, 44, 47, 52, 66, 314, 351, 429, 521, 522, 523.

This species is usually rare or very rare and small, but at a few stations, notably WS 429 and 521 it is very common and well developed. At WS 33 it is common, but all the specimens are small; at WS 25 they are frequent but pauperate.

277. **Globigerina triloba**, Reuss (F 305).

Nine stations: 133, 149; WS 47, 351, 429, 521, 522, 523; MS 14.

Very common at WS 521, common at WS 522, frequent at WS 429 and rare at the remaining stations. At the stations where it occurs in any numbers some of the specimens attain a large size.

278. **Globigerina inflata**, d'Orbigny (F 306).

Ten stations: 131, 149; WS 28, 314, 351, 429, 521, 522, 523; MS 14.

Extremely common at WS 521 and 522, and common at WS 429. Rare or very rare at the other stations. At most of the stations a very thick-walled type is dominant, but at St. 149 a thin-walled type only occurs.

279. **Globigerina dutertrei**, d'Orbigny (F 307).

Thirty-eight stations: 15, 20, 23, 27, 31, 45, 123, 131, 133, 136, 138, 139, 140, 144, 149, 660; WS 20, 28, 32, 33, 36, 38, 40, 41, 42, 43, 44, 63, 66, 154, 314, 351, 428, 429, 521, 522; MS 14, 68.

Typical specimens are always rare or very rare, which in fact is the general record of the species in the area. A form intermediate between *G. dutertrei* and *G. pachyderma* is, however, extremely common at WS 429, 521 and 522, and rare at many other stations. It is more compact than the type, the chambers being less inflated and the aperture a large hooded arch directed inwards towards the umbilicus. The two forms often occur together, especially at WS 522. The best typical specimens are found at stations where the *pachyderma* variety does not occur, notably at Sts. 27, 45 and 144. Intermediate varieties are frequent.

280. **Globigerina conglomerata**, Schwager (F 308).

Sixteen stations: 30, 45, 133, 138, 139, 144, 149; WS 28, 33, 36, 44, 314, 351, 429, 522, 523.

Very common at WS 429 and 522, common at WS 314 and 523, frequent at St. 45 and rare or very rare at the remaining stations. The best and most typical specimens at Sts. 45, 149, WS 314 and 522. There is great variation in development. At WS 429 a complete series running into *G. pachyderma* was obtained.

281. **Globigerina pachyderma** (Ehrenberg) (F 310).

Fifty-two stations: 14, 16, 17, 20, 23, 30, 31, 42, 45, 131, 136, 138, 140, 143, 144, 145, 149, 157, 660; WS 20, 25, 27, 32, 33, 36, 37, 40, 41, 42, 43, 44, 45, 50, 63, 63–4, 66, 113, 154, 314, 349, 351, 361, 373, 418, 426, 428, 429, 521, 522, 523; MS 14, 68.

Almost universally distributed and often extremely abundant, notably at WS 63, 63–4, 314, 418, 429, 521, 522 and 523. At many of these stations it is the dominant species and forms a high percentage of the organic remains. There are, however, many stations at which it is very rare. There is a wide range of variety in the size and development of the species. At WS 25, where it is frequent, the specimens are all small and thick walled, and the aperture a mere central puncture. Between this and a large thin-walled form with large arched aperture every degree of variation is to be found.

282. **Globigerina rubra**, d'Orbigny (F 311).

Five stations: WS 25, 32, 41, 47; MS 68.

Only a single very small specimen at each of the WS stations, and three small specimens at MS 68.

283. **Globigerina conglobata**, Brady.

Globigerina conglobata, Brady, 1879, etc., RRC, 1879, p. 286; 1884, FC, p. 603, pl. lxxx, figs. 1–5.
Globigerina conglobata, Brady, Parker and Jones, 1888, AB, p. 225, pl. xlv, fig. 13.
Globigerina conglobata, Cushman, 1918, etc., FAO, 1924, p. 18, pl. iii, figs. 8–13.

Two stations: 149; WS 52.

One very small but typical specimen occurs at a depth of 184 m. at WS 52 off the western extremity of South Georgia, and four small specimens at St. 149 in Cumberland Bay. The southern range of this species is given by Brady as about 35° S, and the specimens from St. 149 would not be above suspicion (see note on station, p. 37) but for the occurrence of the specimen from the other end of the island.

284. **Globigerina elevata**, d'Orbigny (F 312).

Six stations: 15, 149; WS 18, 428, 429, 521.

Very common at WS 429, rare or very rare at the other stations, but good specimens at all.

Genus **Orbulina**, d'Orbigny, 1826

285. **Orbulina universa**, d'Orbigny (F 314).

One station: 149.

The occurrence of several well-grown individuals at St. 149 only inside Cumberland Bay (200–234 m.) is not easily accounted for, and they should perhaps be disregarded as "strays" (see note on station, p. 37).

Genus **Pullenia**, Parker and Jones, 1862

286. **Pullenia sphaeroides** (d'Orbigny) (F 315).

Six stations: 148; WS 351, 428, 429, 522, 523.

Always rare. The finest specimens were at WS 522, where great size was attained. More numerous but much smaller at WS 429 and 523.

287. **Pullenia subcarinata** (d'Orbigny) (F 316).

Thirty stations: 20, 27, 30, 123, 126, 136, 140, 144, 148, 149; WS 27, 28, 33, 40, 42, 43, 47, 48, 52, 63, 113, 154, 314, 334, 348, 357, 418, 429, 522; MS 68.

Very variable in its frequency, abundant at some stations, notably WS 27 and 33. Here, as might be expected, there was a great range of variation: specimens inseparable from *P. quinqueloba* were noticed at many stations, but as we have already explained in our Falkland Report we can see no reason for separating Reuss's species from the earlier species of d'Orbigny, the two being linked by endless variations.

288. **Pullenia obliquiloculata**, Parker and Jones (F 317).

Two stations: 30; WS 522.

A thick-walled variety is very common in the deep water *Globigerina* oozes of WS 522. This is the only record except a single small specimen from St. 30, which is in Cumberland Bay (251 m.). Its presence there and the presence of *Orbulina universa* at a neighbouring station are probably due to the influence of currents.

Genus **Sphaeroidina**, d'Orbigny, 1826

289. **Sphaeroidina bulloides**, d'Orbigny.

Sphaeroidina bulloides, d'Orbigny, 1826, TMC, p. 267, no. 1, Modèle no. 65.
Sphaeroidina bulloides, Brady, 1884, FC, p. 620, pl. lxxxiv, figs. 1–7.
Sphaeroidina bulloides, Brady, Parker and Jones, 1888, AB, p. 226, pl. xlv, figs. 9–11.
Sphaeroidina bulloides, Cushman, 1918, etc., FAO, 1924, p. 36, pl. vii, figs. 1–6.

One station: WS 522.

A single small but quite typical specimen at a depth of 2550 m. The position of this station is several hundred miles farther south than the highest record given by Brady, which was in the Southern Ocean, at a position of 46° 46′ S, 45° 31′ E with a depth of 1375 fathoms.

Family ROTALIIDAE

Sub-family *SPIRILLININAE*

Genus **Spirillina**, Ehrenberg, 1841

290. **Spirillina vivipara**, Ehrenberg (F 319).

One station: 145.

Two very minute specimens only.

291. **Spirillina obconica**, Brady (F 321).

Two stations: 145, 149.

A single specimen at each station.

292. **Spirillina obconica var. carinata**, Halkyard (F 321 A).

Spirillina vivipara, var. *carinata*, Halkyard, 1889, RFJ, p. 69, pl. ii, fig. 6.
Spirillina vivipara, var. *carinata*, Sidebottom, 1904, etc., RFD, 1908, p. 8, pl. ii. fig. 4.
Spirillina obconica var. *carinata*, Heron-Allen and Earland, 1913, CI, p. 108, pl. ix, figs. 6, 7.

One station: WS 33.

A single specimen.

Sub-family *ROTALIINAE*

Genus **Patellina**, Williamson, 1858

293. **Patellina corrugata**, Williamson (F 326).

Fourteen stations: 30, 123, 140, 144, 145, 149, 157; WS 18, 25, 27, 33, 51, 154, 314.

Never very common except at St. 123, WS 27 and 33. The largest specimens, however, were noted at 149 and WS 25, where the species was comparatively rare. At most stations both circular and oval types occur. Most of the specimens are megalospheric, but microspheric individuals were seen at several stations. The species nowhere attains the large size of some of the Falkland individuals, but is quite up to average dimensions.

Genus **Discorbis**, Lamarck, 1804

294. **Discorbis globularis** (d'Orbigny) (F 331).

Twenty stations: 27, 30, 45, 123, 126, 136, 140, 144, 145, 148, 660; WS 25, 27, 33, 154, 314, 348, 418; MS 14, 68.

Generally distributed and often very abundant. The species occurs both free and sessile and the specimens cover a very wide range of variation in size, convexity and shape. At some of the stations, notably St. 123, WS 25 and 33, specimens grow to a large size and become very irregular with age. Encystment was observed at WS 33 and a budding specimen at WS 25, at which station also specimens were found entirely covered with a Diatom, *Cocconeis* sp.

295. **Discorbis globularis var. anglicus**, Cushman (Plate IV, figs. 26, 27).

Discorbina irregularis, Heron-Allen and Earland (*non* Rhumbler), 1913, CI, p. 120, pl. x, figs. 2–4.
Discorbis globularis, var. *anglica*, Cushman, 1918, etc., FAO, 1931, p. 23, pl. iv, figs. 10 *a–c*.

Two stations: 45; WS 25.

Particularly fine examples of the irregular formation figured by us from Clare Island (*ut supra*) and ascribed to Rhumbler's species, *D. irregularis*, occur at these two stations. Many less wild-growing occur at other stations and were not separated from *D. globularis*.

Cushman has separated our form apparently on account of the absence of the secondary apertures described by Rhumbler. His varietal name is not very happy, as we have found these irregular forms not only in British waters, but wherever *D. globularis* is plentiful.

296. **Discorbis mediterranensis** (d'Orbigny) (F 332).

Five stations: 27, 145; WS 25, 33; MS 68.

Very common at WS 25, frequent to rare at the other stations.

297. **Discorbis vilardeboanus** (d'Orbigny) (F 333).

Four stations: 144, 149; WS 33; MS 68.

Common at St. 149 and MS 68 and very variable in height at the latter station. Rarer at St. 144, where the most typical specimens were found, and very rare at WS 33.

298. **Discorbis rosaceus** (d'Orbigny) (F 334).

Eleven stations: 123, 131; WS 25, 31, 33, 40, 42, 51, 66, 351; MS 68.

Small specimens and rare everywhere, except at Sts. WS 25, 33 and 66. At the first of these it is very common.

299. **Discorbis chasteri** (Heron-Allen and Earland) (F 352).

Two stations: 140; WS 33.

A single large individual at St. 140, many large and small at WS 33.

300. **Discorbis margaritaceus**, sp.n. (Plate IV, figs. 23–25).

One station: WS 25.

Test free, circular in outline, dorsal side convex, peripheral edge rounded, ventral side rounded and sinking into a deep umbilicus; consisting of about two convolutions, six chambers in the final convolution; sutures on dorsal side oblique, flush but strongly marked; sutures on ventral side obscure and flush; dorsal surface granular, ventral surface covered with very minute beads arranged in radial lines across the chambers into the umbilical recess. Aperture a minute slit on inner edge of final chamber. The general aspect of the shell is lustrous or pearly, owing to the diffraction effects produced by the granulation of the dorsal surface, and the beads on the ventral surface which is the brighter of the two.

Diameter up to 0·3 mm., height about 0·05 mm.

A few specimens only of this pretty shell, which is probably allied to *D. parisiensis* (d'Orbigny), were found.

301. **Discorbis subobtusus**, Cushman.

Discorbis subobtusa, Cushman, 1921, FP, p. 304, pl. lxx, fig. 2.

One station: WS 351.

Three specimens found at this station at a depth of 1170 m. agree fairly well with Cushman's figure except in size. They are much smaller, the largest being only 0·35 mm.

in greatest diameter, as compared with 1·5 mm. for his specimens from a depth of 494 fathoms off the Philippines.

Genus Heronallenia, Chapman and Parr, 1930

302. **Heronallenia wilsoni** (Heron-Allen and Earland).

Discorbina wilsoni, Heron-Allen and Earland, 1922, TN, p. 206, pl. vii, fig. 17–19; 1924, FQM, p. 172.
Heronallenia wilsoni, Chapman and Parr, 1931, NAF, p. 237, pl. ix, figs. 7, 8.

Two stations: 17; WS 314.

A single specimen at each station. The original records were from the Antarctic, and showed the same wide variation in depth as the specimens from South Georgia, which were found at depths of 137 and 1950 m. respectively.

Genus Truncatulina, d'Orbigny, 1826

303. **Truncatulina refulgens** (Montfort) (F 355).

Twenty stations: 16, 20, 27, 30, 123, 136, 140; WS 25, 27, 33, 40, 43, 45, 46, 51, 63, 357, 373, 428, 521.

Always rare and often very small. The best specimens at Sts. 16 and 123.

304. **Truncatulina lobatula** (Walker and Jacob) (F 356).

Sixteen stations: 30, 123, 140, 145, 149, 660; WS 18, 25, 27, 33, 40, 66, 110, 348, 521, 522.

Frequent at WS 27, elsewhere rare or very rare and often represented by a single small or immature specimen. The best specimens at St. 149.

305. **Truncatulina dispars**, d'Orbigny (F 357).

One station: WS 32.

Only a single specimen of this species which is so characteristic of the Falkland area.

306. **Truncatulina wuellerstorfi** (Schwager) (F 361).

Two stations: WS 521, 522.

Very rare, but good specimens.

307. **Truncatulina akneriana** (d'Orbigny) (F 362).

Eight stations: 30, 123, 149; WS 25, 27, 33, 113, 522.

Frequent and good specimens at WS 25, rare or very rare elsewhere, but good specimens at WS 27 and 522.

308. **Truncatulina pseudoungeriana** (Cushman) (F 363).

Seventeen stations: 30, 42, 123, 131, 140, 149; WS 25, 27, 33, 42, 66, 113, 154, 314, 348, 428, 521.

Common but small at WS 66. Elsewhere very rare, often only a single specimen, but good and typical, notably at St. 123, WS 33 and 154.

309. **Truncatulina praecincta** (Karrer) (Plate IV, figs. 28–30).

Rotalia praecincta, Karrer, 1868, MFKB, p. 189, pl. v, fig. 7.
Truncatulina praecincta, Brady, 1884, FC, p. 667, pl. xcv, figs. 1–3.
Truncatulina praecincta, Cushman, 1910, etc., FNP, 1915, p. 39, fig. 42 in text, pl. xxvi, fig. 2.

Two stations: 123, 144.

Many excellent specimens, especially at St. 144. They agree even better with Karrer's original figure of the fossil form than with recent figures of the species. Its presence in South Georgia is very anomalous, as recent records appear to be confined to tropical seas.

310. **Truncatulina haidingerii** (d'Orbigny) (F 365).

Four stations: WS 28, 33, 521, 522.

Very rare, never more than one or two at each station, the best at WS 522. The specimens agree very well with Brady's figure but are probably not the same organism as the fossil recorded by d'Orbigny from the Vienna Basin, if his figure of the latter is reliable.

311. **Truncatulina robertsoniana**, Brady.

Truncatulina robertsoniana, Brady, 1879, etc., RRC, 1881, p. 65; 1884, FC, p. 664, pl. xcv, fig. 4.
Cibicides robertsoniana, Cushman, 1918, etc., FAO, 1931, p. 121, pl. xxiii, fig. 6.

One station: WS 27.

A single small specimen referred with some doubt to this species. While presenting most of the typical features, the sutures on the dorsal side are more oblique than usual.

312. **Truncatulina tumidula**, Brady (F 366).

Six stations: WS 33, 428, 429, 521, 522, 523.

Very common at WS 429 at a depth of 2549 m.; rare to very rare at the other stations.

313. **Truncatulina bradyana** (Cushman) (F 367).

Two stations: WS 33, 521.

All the specimens are very poor except at WS 521. It is very rare at both stations.

Genus Anomalina, d'Orbigny, 1826

314. **Anomalina vermiculata** (d'Orbigny) (F 369).

Three stations: 30, 149; WS 27.

Extremely rare. A nearly fully developed specimen was found at St. 149. At WS 27 two well-developed specimens in the intermediate stage occurred and a similar one at St. 30. The rarity of the species as compared with its abundance in the Falkland area is no doubt due to the difference of temperature.

Genus **Globorotalia**, Cushman, 1927

315. **Globorotalia hirsuta** (d'Orbigny) (F 374).

Six stations: WS 28, 351, 429, 521, 522, 523.

Common at WS 522 as a large thick-walled bottom form. Very rare at all the other stations.

316. **Globorotalia scitula** (Brady) (F 375).

Three stations: 138; WS 351, 522.

Rare. The specimens exhibit every degree of variation in the thickness of the walls of the test.

317. **Globorotalia crassa** (d'Orbigny) (F 376).

Five stations: 149; WS 429, 521, 522, 523.

A large and thick-walled benthic form is very common at WS 523, and a small thick-walled form is equally abundant at WS 521. Otherwise the species is rare but very good and typical, especially at St. 149 and WS 522.

318. **Globorotalia truncatulinoides** (d'Orbigny) (F 377) (Plate IV, figs. 35–7).

Five stations: 149; WS 33, 351, 521, 522.

Common or very common at WS 521 and 522. The majority of the specimens at these stations belong to a large and very thick-walled form with slightly convex dorsal surface. It is very distinctive and may prove to be specifically different from the small thin-walled type which occurs, but very rarely, at the other stations.

Genus **Pulvinulina**, Parker and Jones, 1862

319. **Pulvinulina berthelotiana** (d'Orbigny) (F 383).

One station: WS 522.

A few specimens from *Globigerina* ooze (2550 m.) appear to agree in general with d'Orbigny's species. But although the sutures are heavily limbate on the dorsal side, they are depressed on the ventral.

320. **Pulvinulina punctulata** (d'Orbigny).

Rotalia punctulata, d'Orbigny, 1826, TMC, p. 273, No. 25, Modèle No. 12.
Pulvinulina repanda var. *punctulata*, Parker and Jones, 1865, NAAF, p. 394, pl. xiv, figs. 12, 13.
Pulvinulina punctulata, Brady, 1884, FC, p. 685, pl. civ, fig. 17.
Eponides punctulata, Cushman, 1918, etc., FAO, 1931, p. 48, pl. x, fig. 6.

One station: WS 27.

A single very fine specimen about 3 mm. in diameter.

321. **Pulvinulina elegans** (d'Orbigny) (F 385).

One station: WS 522.

Rare but large and typical shells.

322. **Pulvinulina umbonata** (Reuss) (F 386).

Two stations: WS 429, 522.

Very rare. All the specimens, though typical, are small, except one very large shell at WS 522.

323. **Pulvinulina exigua**, Brady (F 387).

Eight stations: 15, 145; WS 33, 42, 429, 521, 522; MS 68.

Frequent at WS 33, elsewhere rare or very rare; but some very good specimens at WS 522.

324. **Pulvinulina karsteni** (Reuss) (F 391).

Thirty-eight stations: 13, 14, 16, 20, 23, 27, 42, 45, 123, 126, 131, 136, 140, 144, 148, 149, 157; WS 25, 27, 28, 33, 37, 40, 41, 42, 43, 45, 48, 50, 66, 113, 154, 348, 349, 357, 418, 521; MS 14.

Although generally distributed in the area, the species is usually rare. It is, however, very common at St. 144 and WS 28, and common or frequent at Sts. 45, 126, 149, WS 33, 154 and 349. The most generally distributed type is bi-convex, with a somewhat flattened dorsal side, but practically all the variations noted in the Falkland area were observed. At WS 27 a small form with the dorsal surface quite flat occurs, all the convolutions are visible and the ventral surface is highly conical. This form occurs also at 140 and 144, in company with the normal type and intermediate variations. Very large specimens were observed at several stations, notably St. 27.

325. **Pulvinulina peruviana** (d'Orbigny) (F 392).

Seven stations: 27, 42, 144, 148; WS 25, 27, 33.

Very common at St. 144, frequent at St. 27 and WS 27, but elsewhere very rare. Some very large specimens at WS 27.

326. **Pulvinulina pauperata**, Parker and Jones.

Pulvinulina pauperata, Parker and Jones, 1865, NAAF, p. 395, pl. xvi, figs. 50, 51 *a*, *b*.
Pulvinulina pauperata, Brady, 1884, FC, p. 696, pl. civ, figs. 3–11.
Pulvinulina pauperata, Flint, 1899, RFA, p. 330, pl. lxxiv, fig. 3.
Laticarinina pauperata, Cushman, 1918, etc., FAO, 1931, p. 114, pl. xx, fig. 4, pl. xxi, fig. 1.

One station: WS 522.

Several fairly large specimens from a depth of 2550 m.

Genus Rotalia, Lamarck, 1804

327. **Rotalia beccarii** (Linné) (F 393).

Three stations: 20, 149; WS 25.

Two specimens at WS 25 and one at each of the other stations. All typical but rather small.

328. **Rotalia soldanii, d'Orbigny** (F 394 A).

Four stations: WS 429, 521, 522, 523.

Many large and typical specimens at WS 521 and 522, pauperate or young only at the other stations.

Family NUMMULINIDAE

Sub-family *NONIONINAE*

Genus Nonion, Montfort, 1808

329. **Nonion depressulum** (Walker and Jacob) (F 399).

Forty-five stations: 13, 16, 20, 23, 27, 30, 31, 42, 45, 123, 126, 131, 140, 144, 148, 149, 157, 660; WS 20, 25, 27, 28, 33, 37, 40, 42, 43, 45, 46, 47, 48, 50, 52, 63, 63–4, 66, 113, 154, 314, 349, 357, 418, 522; Drygalski Fjord; MS 68.

Generally distributed, very common at WS 50, common at Sts. 20, 45, 144, 149 and MS 68, varying from frequent to rare elsewhere. The best series at Sts. 45, 149 and MS 68.

The specimens are not in agreement with the British type but do not present sufficient difference to warrant specific separation. The type from South Georgia is somewhat inflated with flush thick sutures and an unbroken peripheral edge. The umbilicus well marked owing to the coalescence of the ends of the sutural lines, but not so pronounced as in the figure which Brady gives of *N. asterizans* (B. 1884, FC, pl. cix, figs. 1, 2).

330. **Nonion asterizans** (Fichtel and Moll) (F 400).

Three stations: 136; WS 79, 255.

Very rare and pauperate.

331. **Nonion orbiculare** (Brady).

Nonionina orbicularis, Brady, 1881, HNPE, p. 105, pl. ii, fig. 5 *a*, *b*; 1884, FC, p. 727, pl. cix, figs. 20, 21.
Nonion orbiculare, Cushman, 1918, etc., FAO, 1930, p. 12, pl. v, figs. 1–3.

Two stations: 131; WS 37.

A few rather doubtful specimens, which are nearer to Brady's species than any other with which I am acquainted.

332. **Nonion umbilicatulum** (Walker and Jacob) (F 401).

Twenty stations: 13, 16, 45, 123, 131, 136, 140, 143, 144, 149; WS 33, 42, 63–4, 113, 349, 351, 418, 429, 521, 522.

Always rare except at WS 429, where it is frequent and typical. Good specimens also at Sts. 16, 123, WS 113, 521 and 522, but elsewhere always weak and far from typical.

333. **Nonion pompilioides** (Fichtel and Moll) (F 402).

Three stations: 660; WS 63–4, 349.

Very rare, only one or two specimens at each station.

334. **Nonion sloanii** (d'Orbigny) (F 403).

Three stations: WS 37, 47, 154.

Rare, but very good specimens at WS 154. Very rare elsewhere.

335. **Nonion stelligerum** (d'Orbigny) (F 404).

One station: WS 429.

Very rare.

336. **Nonion boueanum** (d'Orbigny) (F 405).

Nine stations: 123, 131, 136, 144, 149; WS 40, 42, 113, 349.

Very good specimens are frequent at Sts. 136, 144, 149, the best at 149. At the other stations this species is rare or very rare, but still typical.

337. **Nonion grateloupi** (d'Orbigny) (F 406).

One station: 144.

Very rare and pauperate, hardly separable from *N. sloanii*.

338. **Nonion scapha** (Fichtel and Moll) (F 407).

Nineteen stations: 16, 20, 23, 30, 31, 42, 123, 131, 144; WS 27, 28, 33, 40, 43, 50, 348, 349, 418, 429.

Very rare except at St. 123, WS 40 and 349, where it is frequent. Specimens are rather small but quite typical except for a frequent tendency to inequilateral disposition of the chambers, especially noticeable in specimens from WS 43. These inequilateral specimens are inseparable from *Nonionella* and are evidence that, however convenient from a taxonomic point of view, the genus *Nonionella* has no zoological value.

Genus **Nonionella**, Cushman, 1926

339. **Nonionella iridea**, Heron-Allen and Earland (F 410).

Forty-three stations: 14, 15, 20, 23, 30, 31, 42, 45, 123, 126, 131, 136, 140, 144, 148, 149, 157, 660; WS 25, 27, 32, 33, 37, 40, 42, 43, 45, 47, 48, 50, 63, 63–4, 113, 154, 314, 349, 351, 418, 429, 521, 522, 523; MS 68.

Universally distributed and perhaps the most typical species of the area round South Georgia. It is common or very common at many stations, notably St. 144 and WS 33, 429 and 523, but rare at some others.

340. **Nonionella turgida** (Williamson).

Rotalina turgida, Williamson, 1858, RFGB, p. 50, pl. iv, figs. 95–7.
Nonionina turgida, Brady, 1884, FC, p. 731, pl. cix, figs. 17–19.
Nonionina turgida, Cushman, 1918, etc., FAO, 1930, p. 15, pl. vi, figs. 1–4.

Five stations: 15, 45, 131, 149; WS 33.

Always rare or very rare except at St. 149 where it is frequent.

Genus **Elphidium**, Montfort, 1808

341. **Elphidium incertum** (Williamson) (F 412).

Four stations: 140; WS 28, 46, 348.

Very rare and very far from typical, the sutural openings being confined to the neighbourhood of the umbilicus.

342. **Elphidium articulatum** (d'Orbigny) (F 414).

Two stations: 149; WS 314.

Only a single small specimen at each station.

343. **Elphidium alvarezianum** (d'Orbigny) (F 415).

One station: 30.

A single small specimen only.

344. **Elphidium lessonii** (d'Orbigny) (F 417).

Two stations: 145; WS 25.

Extremely rare. A single small specimen only at WS 25. Several good specimens at St. 145, but still very small compared with the dimensions attained in the Falkland area.

345. **Elphidium owenianum** (d'Orbigny) (F 419).

Three stations: WS 25, 27, 33.

Very rare, only a few small specimens at each station, the best at WS 25.

APPENDIX

A No. 130. *Turritellella laevigata*. While this report was in the press, I received for identification some specimens which had been collected in shore sands of the Torbay area, South Devon, by Mr E. Milton, F.R.M.S., of Torquay. They are unquestionably referable to this species, differing only from the South Georgia specimens in their smaller size (the largest is only 0·34 mm. long), and slightly darker colour, due to the presence of more iron in the cement.

Their occurrence is one more instance of the mysteries of distribution. Perhaps in time we shall obtain intermediate records, but in the meantime such widely separated records illustrate the futility of many theories based only on local lists of faunas.

B The genus *Miliammina* has now been recorded as a fossil from the Upper Cretaceous of Manitoba. A new species, *Miliammina manitobensis*, Wickenden, is described and figured in *New Species of Foraminifera from the Upper Cretaceous of the Prairie Provinces* (Robert T. D. Wickenden, Trans. Roy. Soc. Canada, ser. 3, XXVI, Sect. iv, 1932, p. 90, pl. i, figs. 11 *a–c*).

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PLATES I–VII

PLATE I

Figs. 1–4. *Flintia soluta*, sp.n. (No. 11): × 15. Figs. 1, 2, edge views. Fig. 3, front view. Fig. 4, end-oral view.

Figs. 5–7. *Cornuspira diffusa*, Heron-Allen and Earland (No. 32): × 25. Figs. 5, 6, fragments. Fig. 7, abnormal fragment.

Figs. 8, 9. *Astrorhiza triangularis*, sp.n. (No. 36): × 16.

Figs. 10–12. *Pelosina fusiformis*, sp.n. (No. 41): × 19. Fig. 10, specimen with produced neck. Fig. 11, neck broken away. Fig. 12, in section.

Figs. 13–15. *Pelosina variabilis*, Brady, var.n. *constricta* (No. 43). Fig. 13, a South Georgia specimen: × 14. Figs. 14, 15, Antarctic specimens: × 6.

Figs. 16–21. *Vanhoeffenella gaussi*, Rhumbler (No. 38): × 21. Fig. 16, early stage. Figs. 18, 19, advanced stages. Figs. 17, 20, 21, stages of subdivision.

Fig. 22. *Vanhoeffenella oculus*, sp.n. (No. 39): × 21.

Figs. 23, 24. *Storthosphaera elongata*, Cushman, var.n. *impudica* (No. 45): × 18.

Fig. 25. *Bathysiphon rufescens*, Cushman (No. 52): × 14.

Fig. 26. *Bathysiphon capillare*, de Folin (No. 51): × 15.

Fig. 27. *Psammosphaera rustica*, Heron-Allen and Earland (No. 58): × 19.

Figs. 28, 29. *Proteonina decorata*, sp.n. (No. 63): × 26. Fig. 28, side view. Fig. 29, end-oral view.

Figs. 30, 31. *Proteonina tubulata* (Rhumbler) (No. 64): × 21.

Fig. 32. *Astrorhiza limicola*, Sandahl (No. 34): × 9. Specimen incorporating sponge spicules.

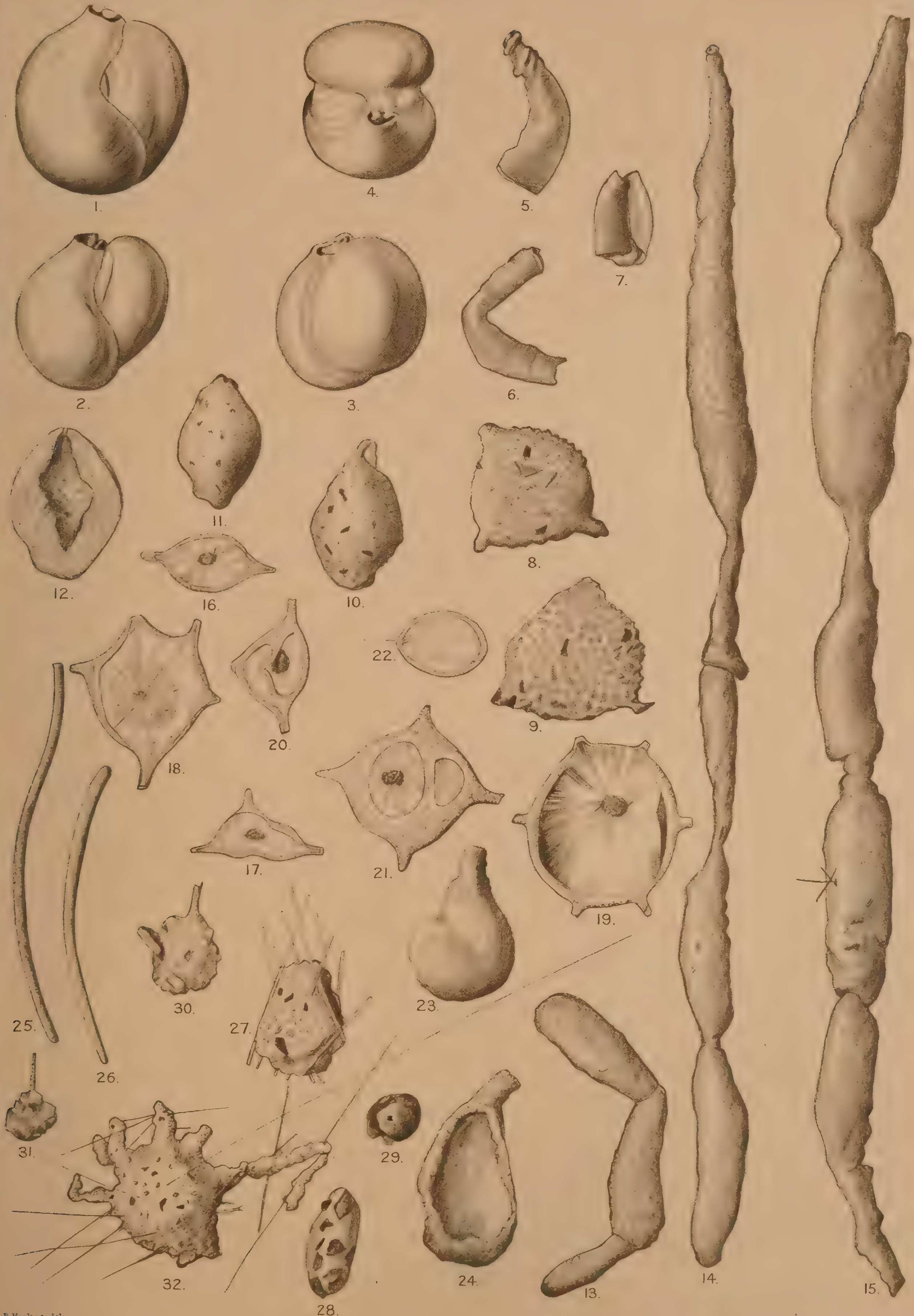
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PLATE II

Figs. 1, 2. *Webbinella limosa*, sp.n. (No. 66): × 13. Fig. 2 shows a specimen laid open, with ingested diatoms.

Figs. 3–10. *Thurammina protea*, sp.n. (No. 76). Figs. 3, 4, sessile specimens in cavity of *Hyperammina*: × 12. Figs. 5, 6, 8–10, free specimens illustrating range of form: × 17. Fig. 7, a specimen built round sponge spicules: × 18.

Fig. 11. *Jaculella obtusa*, Brady (No. 78): × 30.

Figs. 12–15. *Hippocrepina flexibilis* (Wiesner) (No. 81): × 40. Fig. 12, collapsed specimen. Fig. 14, oral view. Fig. 15, specimen in balsam viewed as a transparent object. The dark masses are protoplasm.

Figs. 16–19. *Reophax subfusiformis*, sp.n. (No. 96): × 19.

Fig. 20. *Reophax spiculifer*, Brady (No. 100): × 45.

Fig. 21. *Reophax distans*, Brady, var.n. *gracilis* (No. 105): × 40. A reconstructed specimen.

Fig. 22. *Ammobaculites agglutinans* (d'Orbigny) (No. 116): × 52.

Figs. 23–6. *Ammobaculites bargmanni*, sp.n. (No. 118): × 15. Fig. 23, immature stage. Figs. 24, 25, adult stage. Fig. 26, edge-oral view.

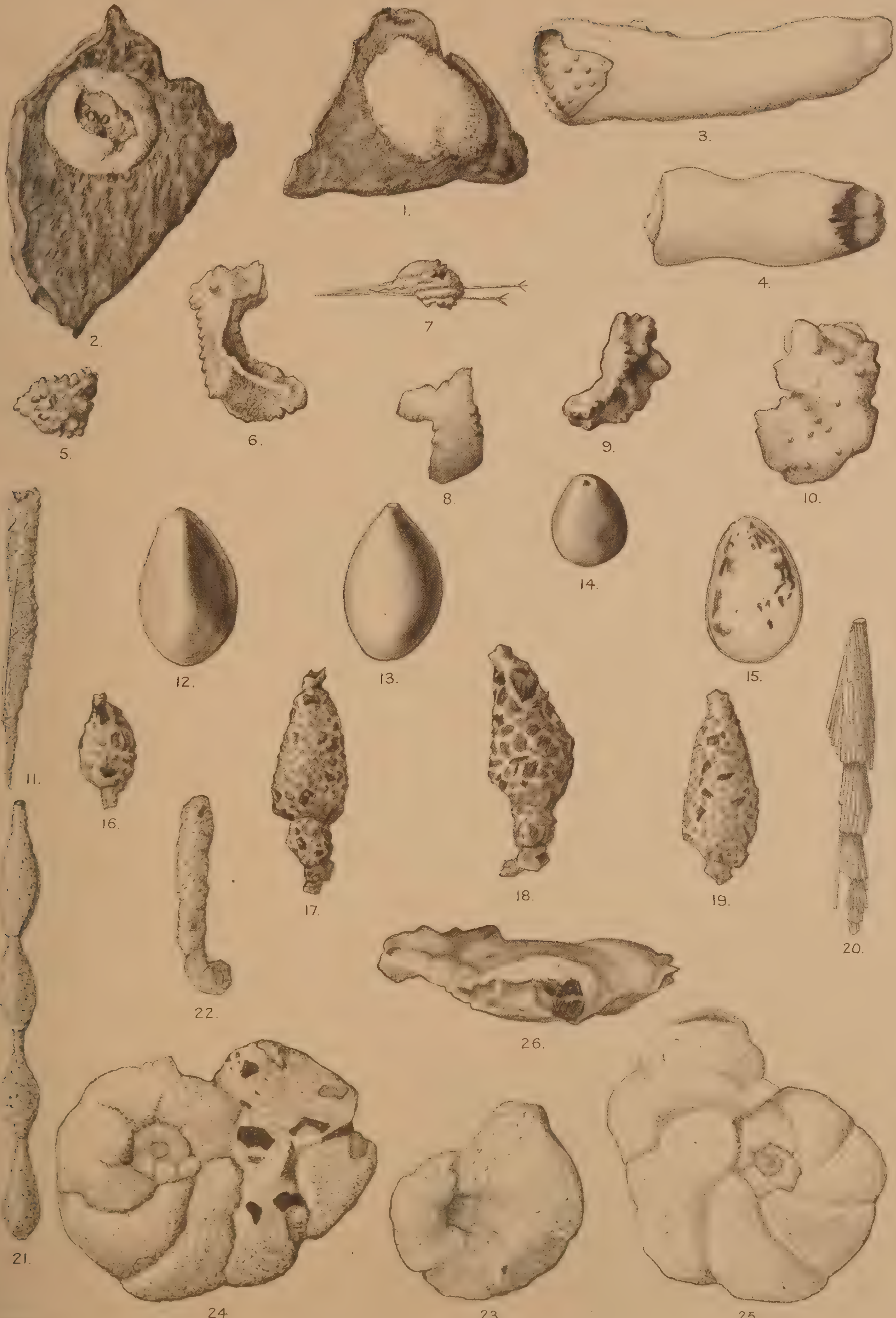
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PLATE III

Figs. 1–4. *Ammomarginulina ensis*, Wiesner (No. 122): × 50. Fig. 1, viewed as a transparent object. Figs. 2, 3, side views. Fig. 4, edge view.

Figs. 5–8. *Turritellella laevigata*, sp.n. (No. 130): × 40. Fig. 8, viewed as a transparent object.

Figs. 9, 10. *Turritellella shoneana* (Siddall) (No. 129): × 70. Fig. 9, megalospheric form. Fig. 10, microspheric form.

Figs. 11, 12. *Haplophragmoides scitulum* (Brady) (No. 112): Oval variety. × 30. Fig. 11, side view. Fig. 12, edge-oral view.

Fig. 13. *Haplophragmoides canariensis* (d'Orbigny) (No. 109): × 17. Abnormal specimen with young shells attached.

Figs. 14–16. *Nouria harrisii*, Heron-Allen and Earland (No. 146): × 32.

Fig. 17. *Miliammina lata* (No. 151) and *M. oblonga*, Heron-Allen and Earland: × 45. Abnormal individual incorporating both species.

Figs. 18–20. *Textularia wiesneri*, sp.n. (No. 155): × 75. Figs. 18, 19, front views. Fig. 20, edge-oral view.

Figs. 21–30. *Textularia tenuissima*, nom.n. (No. 156). Figs. 21–3 × 75: Figs. 24–30 × 70. Figs. 23–5 are drawn from balsam-mounted specimens, the others from opaque specimens. Figs. 21, 22, microspheric forms. Figs. 23–30, megalospheric A1 and A2.

Figs. 31–5. *Textularia nitens*, sp.n. (No. 157). Figs. 31, 32, microspheric, opaque: × 55. Fig. 33, megalospheric, opaque: × 55. Fig. 34, microspheric, transparent: × 60. Fig. 35, megalospheric, transparent: × 60.

Figs. 36–8. *Bigenerina minutissima*, sp.n. (No. 158): × 70.

Figs. 39–42. *Clavulina communis*, d'Orbigny (No. 165): × 43. Fig. 39, young, edge view. Fig. 40, young, oral view.

Figs. 43–6. *Verneuilina advena*, Cushman (No. 159). Figs. 43, 44, opaque: × 65. Figs. 45, 46, transparent: × 60.

Fig. 47. *Bulimina elegantissima*, d'Orbigny (No. 172): × 42. Plastogamic specimens.

Figs. 48, 49. *Bolivina decussata*, Brady (No. 184): × 60. Fig. 48, front view. Fig. 49, edge view.

Figs. 50, 51. *Bolivina difformis* (Williamson) (No. 181): × 66. Fig. 50, front view. Fig. 51, edge view.

Fig. 52. *Lagena acuticosta*, Reuss (No. 197). Abnormal double specimen: × 52.

PLATE III.

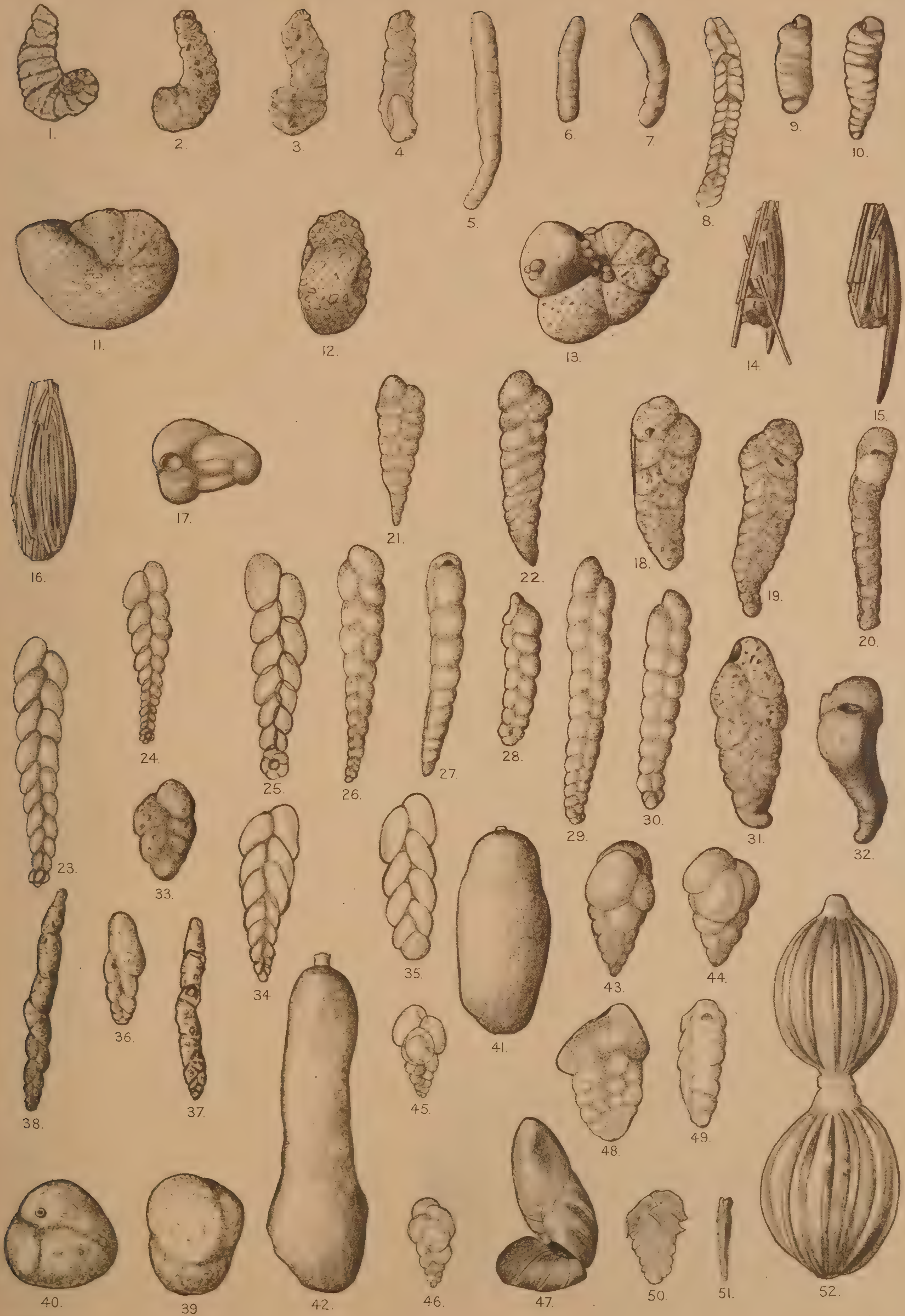
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PLATE IV

Figs. 1–3. *Lagena apiculata* (Reuss) (No. 200) Variety: × 39. Fig. 2, oral view. Fig. 3, aboral view.

Figs. 4, 5. *Lagena felsinea*, Fornasini (No. 212): × 35. Fig. 4, oral view. Fig. 5, side view.

Figs. 6, 7. *Lagena macroptera* (Seguenza) (No. 231): × 30. Fig. 7, edge view.

Figs. 8, 9. *Lagena ventricosa*, A. Silvestri (No. 249): × 30. Fig. 8, side view. Fig. 9, oral view.

Figs. 10, 11. *Lagena herdmani*, sp.n. (No. 221): × 60. Fig. 10, side view. Fig. 11, edge view.

Figs. 12, 13. *Lagena hartiana*, sp.n. (No. 220): × 42. Fig. 12, side view. Fig. 13, edge view.

Figs. 14, 15. *Lagena mackintoshiana*, sp.n. (No. 230): × 34. Fig. 14, side view. Fig. 15, oral view.

Figs. 16–18. *Lagena formosa*, Schwager, var.n. *costata* (No. 215): × 55. Figs. 16, 17, side views. Fig. 18, edge view.

Fig. 19. *Nodosaria calomorpha*, Reuss (No. 254): × 48.

Figs. 20–2. Abnormal *Globigerinae* with young individuals attached: × 40. See p. 120.

Figs. 23–5. *Discorbis margaritaceus*, sp.n. (No. 300): × 35. Fig. 23, dorsal view. Fig. 24, ventral view. Fig. 25, edge-oral view.

Figs. 26, 27. *Discorbis globularis* var. *anglicus*, Cushman (No. 295). Fig. 26, dorsal view: × 47. Fig. 27, ventral view: × 40.

Figs. 28–30. *Truncatulina praecincta*, Karrer (No. 309): × 52. Fig. 28, dorsal view. Fig. 29, ventral view. Fig. 30, edge-oral view.

Figs. 31–4. *Hippocrepina indivisa*, Parker (No. 79): × 55. Fig. 33, normal type. Fig. 34, apertural view of same. Fig. 31, abnormal specimen with irregular aperture. Fig. 32, apertural view of same.

Figs. 35–7. *Globorotalia truncatulinoides* (d'Orbigny) (No. 318): × 52. Fig. 35, dorsal view. Fig. 36, ventral view. Fig. 37, edge-oral view.

Figs. 38–40. *Trochammina malovensis*, Heron-Allen and Earland (No. 135): × 35. Variety with flattened dorsal surface. Fig. 38, ventral view. Fig. 39, edge-oral view. Fig. 40, dorsal view.

Fig. 41. *Lagena marginata* var. *quadricarinata*, Sidebottom (No. 233): × 40.

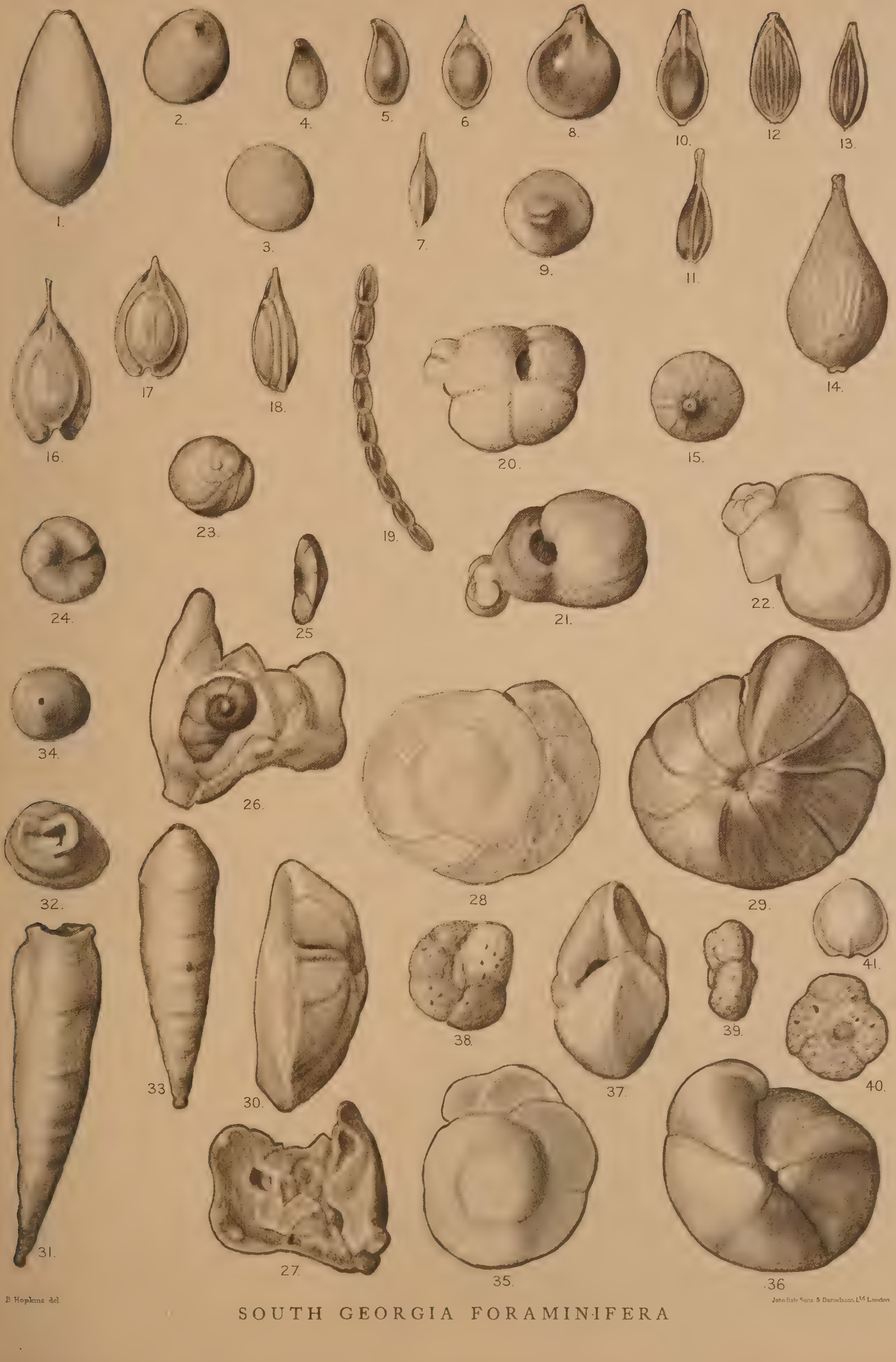
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PLATE V

Figs. 1–5. *Miliammina oblonga*, Heron-Allen and Earland (No. 149): × 50. Fig. 1, front view. Fig. 2, back view. Fig. 3, front view. Fig. 4, edge view. Fig. 5, oral view.

Fig. 6. *Miliammina arenacea* (Chapman) (*sub* No. 149). Isomorphous with *Miliolina oblonga* (Montagu). Drawn from an Antarctic specimen, the species not being found in South Georgia. Front view: × 50.

Figs. 7, 8. *Miliammina oblonga*, Heron-Allen and Earland (No. 149): × 50. Fig. 7, viewed as a transparent object; front view. Fig. 8, viewed as a transparent object; edge view.

Figs. 9–14. *Miliammina obliqua*, Heron-Allen and Earland (No. 150): × 50. Fig. 9, back view. Fig. 10, front view. Fig. 11, edge view. Fig. 12, front view. Fig. 13, young specimen; front view. Fig. 14, oral view.

Figs. 15–19. *Miliammina lata*, Heron-Allen and Earland (No. 151): × 50. Fig. 15, front view. Fig. 16, edge view. Fig. 17, back view. Fig. 18, abnormal specimen; front view. Fig. 19, oral view of normal specimen.

Figs. 20, 21. *Sorosphaera depressa*, Heron-Allen and Earland (No. 55). Fig. 20, a young colony attached to a flexible organic base: × 25. Fig. 21, a colony of individuals attached to a stone; several specimens show openings due to accidental fractures: × 8.

Figs. 22–5. *Ammobaculites rostratus*, Heron-Allen and Earland (No. 119): × 17. Fig. 22, using mud for construction of test. Fig. 23, immature specimen. Figs. 24, 25, using sand for construction of test.

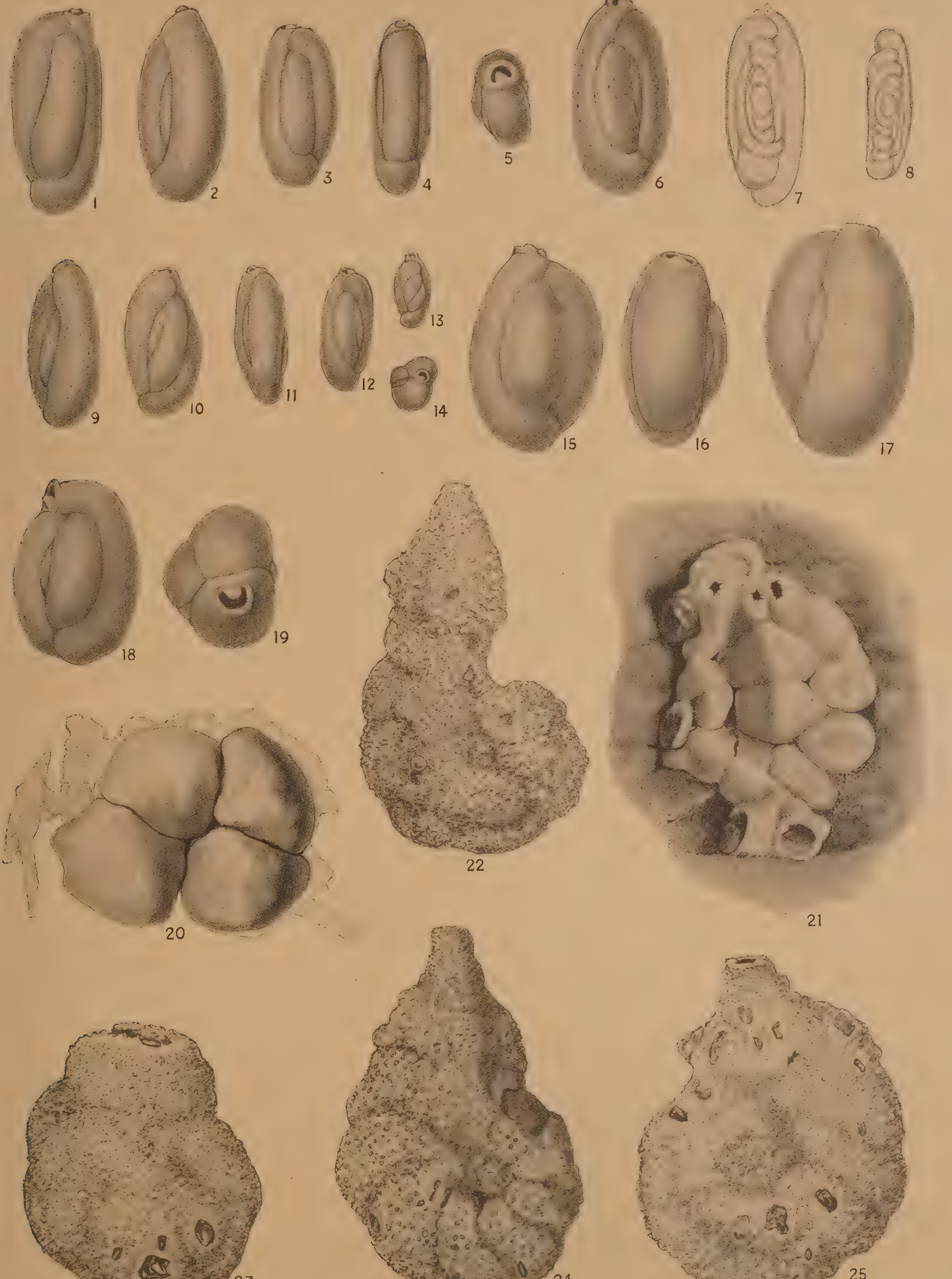
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PLATE VI

Figs. 1–9. *Ehrenbergina crassa*, Heron-Allen and Earland (No. 193): × 90. Figs. 1, 2, megalospheric; edge views. Fig. 3, megalospheric; ventral side. Fig. 4, megalospheric; dorsal side. Fig. 5, microspheric; ventral side. Fig. 6, microspheric; edge view. Fig. 7, microspheric; edge view of specimen in balsam. Fig. 8, microspheric; ventral side of specimen in balsam. Fig. 9, megalospheric; ventral side of specimen in balsam.

Figs. 10–15. *Gordiospira fragilis*, Heron-Allen and Earland (No. 33). Fig. 10, young individual; side view: × 40. Figs. 11, 12, adult individuals; side views: × 30. Fig. 13, adult individual; edge-oral view: × 30. Fig. 14, young individual viewed as a transparent object to show the irregular coiling of the early chambers; protoplasmic body dark: × 160. Fig. 15, young individual viewed as a transparent object to show the irregular coiling of the early chambers; protoplasmic body dark: × 80.

PLATE VI

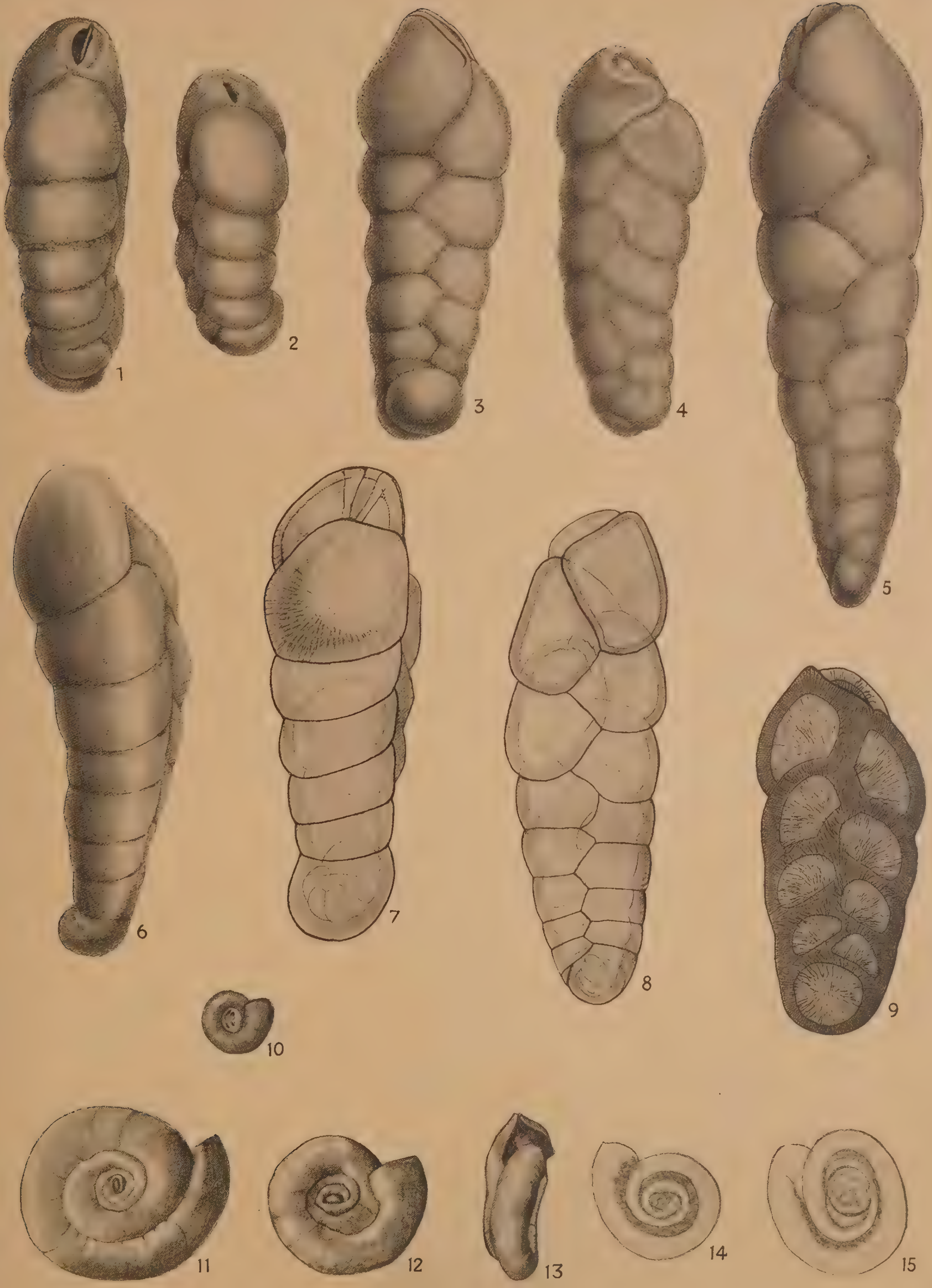
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PLATE VII

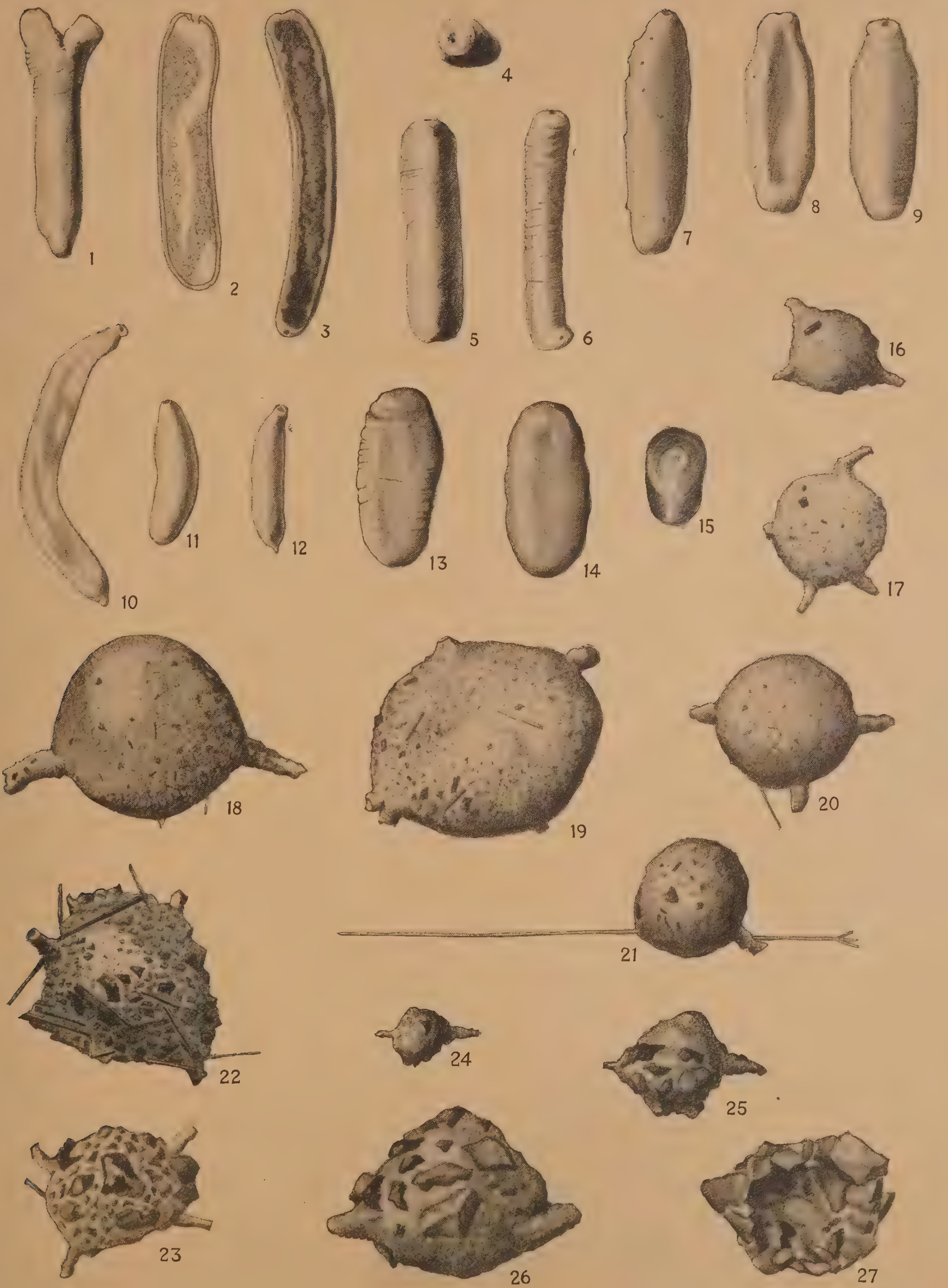
Figs. 1–9. *Hippocrepinella hirudinea*, Heron-Allen and Earland (No. 82). Fig. 1, abnormal individual with bifurcate extremity: × 20. Fig. 2, thin section (transparent) showing protoplasmic body loaded with diatoms: × 20. Fig. 3, opaque section; the variations in the thickness of the wall of the test at different places are due to the angle at which the section is cut: × 20. Fig. 4, oral-end view: × 15. Figs. 5–9, side views illustrating variations in shape due to compression, shrinkage, etc. Figs. 7–9 show accessory openings in the walls, possibly due to parasites: × 20.

Figs. 10–12. *Hippocrepinella alba*, Heron-Allen and Earland (No. 84): × 20. Side views of specimens of various sizes.

Figs. 13–15. *Hippocrepinella hirudinea* var. *crassa*, Heron-Allen and Earland (No. 83): × 24. Figs. 13, 14, side views. Fig. 15, end-oral view.

Figs. 16–23. *Armorella sphaerica*, Heron-Allen and Earland (No. 71). Figs. 16–20, illustrating variations in size, number of tubes, etc.: × 35. Fig. 21, with incorporated sponge spicule: × 25. Fig. 22, using sponge spicules and coarse sand for construction: × 25. Fig. 23, using coarse material for construction: × 25.

Figs. 24–7. *Pelosphaera cornuta*, Heron-Allen and Earland (No. 59): × 9. Fig. 24, young individual. Figs. 25, 26, stages in development. Fig. 27, a specimen laid open; the white lines between the sand grains indicate the highly finished surface of the incorporating cement in the interior of the test, as compared with the rough external layer.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INVESTIGATIONS

ON VERTICAL CIRCULATION IN THE OCEAN DUE TO THE ACTION OF THE WIND WITH APPLICATION TO CONDITIONS WITHIN THE ANTARCTIC CIRCUMPOLAR CURRENT

By

H. U. SVERDRUP

ON VERTICAL CIRCULATION IN THE OCEAN DUE TO THE ACTION OF THE WIND WITH APPLICATION TO CONDITIONS WITHIN THE ANTARCTIC CIRCUMPOLAR CURRENT

By H. U. Sverdrup

(Text-figs. 1–23)

THE theoretical studies of the ocean currents have principally dealt with the horizontal currents which arise because of the effect of the wind and because of the distribution of density. The question as to the relative importance of the wind and the distribution of density has often been discussed and seems now to be answered in favour of the wind. Defant, in his excellent survey of the present status of dynamic oceanography, says (1929, p. 136) that the greater influence on the development of the horizontal currents must be ascribed to the wind, while the differences in density are of special importance to the vertical circulation. In this paper it is intended to show that the wind also maintains systems of vertical circulation and that the factors which influence the density of the sea water, such as heating, cooling, evaporation and precipitation, are of equal importance to the horizontal currents as is the wind. Before doing so it is necessary to give a brief review of our present theoretical knowledge of the ocean currents. Comprehensive investigations have especially been undertaken by Ekman (1928), who has examined the currents which arise in homogeneous and non-homogeneous water both under the action of the wind and as a result of the distribution of density. We shall follow his classification and terminology.

In homogeneous water Ekman discriminates between three different current systems, which all arise under the action of the wind:

(1) *The pure drift current*, which is limited to the uppermost layer in which the current at the surface is directed at 45° *cum sole* from the direction of the wind. With increasing depth this current turns *cum sole* and decreases in velocity until it becomes negligible at the "depth of frictional resistance." Within this current the total transport of the water is directed at 90° *cum sole* from the direction of the wind.

(2) *The slope current*, which arises because the oceans are limited and, therefore, the water is piled up along the coast towards which the transport by the pure drift current is directed. Because of this piling up, the surface of the sea becomes inclined and a current is set up which runs with uniform direction and velocity from the surface to the bottom, except in the immediate vicinity of the bottom where the influence of the friction along the bottom has to be considered. Above the "lower depth of frictional resistance" the slope current is directed at right angles *cum sole* from the direction of the slope. Below the "lower depth of frictional resistance" we find the third constituent of the current system.

(3) *The bottom current*, which is part of the slope current and which reaches from the top of the "lower depth of frictional resistance" to the bottom, and turns *contra solem* with increasing depth.

This current system is illustrated by considering the currents which must arise in a channel of uniform depth, running all around the earth between two parallels of latitude, if a wind of uniform velocity blows in the direction of the channel. With applications to conditions in the Antarctic in mind, it may be supposed that the channel is situated in the southern hemisphere, that the wind blows from west to east, and that the depth is considerably greater than the upper and lower depths of frictional resistance. Within the pure drift current, which is limited to the upper depth of frictional resistance, the transport is directed 90° to the left of the wind, which means in this case to the north. This transport causes a piling up of the water along the northern boundary of the channel and, therefore, the surface of the water must slope downwards from north to south. This slope causes, on the other hand, a current which runs in a direction 90° to the left of the slope, which means in the direction of the wind, from west to east. The velocity and direction of the slope current are the same at all levels, except within the bottom layer. When approaching the bottom the current turns to the right and decreases. Between the top of the lower depth of frictional resistance and the bottom, the total transport has a component in the direction of the slope, which means from north to south. Stationary conditions can exist when the total transport towards the north by the pure drift current above the depth of frictional resistance equals the transport towards the south below the lower depth of frictional resistance. On the assumption that the upper and the lower depths of frictional resistance are the same, Ekman has found that the velocity of the slope current must be equal to the velocity of the pure drift current at the surface multiplied by $\sqrt{2}$.

Thus, the principal effect of the wind is to uphold a slope current in the direction of the wind and in addition to maintain a transversal circulation, which in the upper layer transports water from south to north and near the bottom transports water from north to south. At the northern boundary descending motion, and at the southern boundary ascending motion must take place because of the continuity. The problem has not been treated in three dimensions, but supposing the depth of the channel to be small in comparison with the width, the vertical components of the currents must always remain small and, therefore, it is improbable that a complete analysis would give results which would deviate considerably from the above.

The simple system of three currents, the pure drift current, the slope current and the bottom current is modified if the water is non-homogeneous. In this case the isosteres are generally not horizontal and, therefore, currents must be present which are due to the distribution of density or in Ekman's terminology "*convection currents*." The velocity and direction of these currents can be computed by means of the Bjerknes theorem of circulation. Ekman considers the convection current as the fourth constituent of the currents in the sea. He points out that the greatest changes of density in a horizontal direction are found in the upper layers, from the surface to 1000 m. or less, and that in the deep water the isosteres are nearly horizontal. This implies that the greatest number of solenoids in the sense of Bjerknes are present in the upper layers and that very few or no solenoids are found in the deep water. Consequently the velocity of the convection currents decreases rapidly with depth and approaches zero at great depth, contrary to the velocity of the slope current, which remains constant from the surface to the top of the lower layer of frictional resistance.

Ekman, furthermore, points out that in a sea in which the density increases with depth, a pure drift current must give rise to a convection current, running generally in the direction of the wind. In order to illustrate this effect of the wind we may again consider the channel around the earth, but now we will assume that the water is not homogeneous but that the density increases with depth. The immediate effect of a pure drift current will be to transport the light surface water towards the left-hand side of the channel and, therefore, near the surface the isosteres cannot remain horizontal but must soon slope downwards from south to north. In the upper layers the light water is accumulated on the left-hand side of the wind and we get a solenoid field which must cause a current in the direction of the wind, but the velocities within this current decrease downwards since the inclination of the isosteres decreases. At the same time we may get a piling up of the water at the northern boundary, and as a result of this a slope current may arise, which also runs in the direction of the wind but remains constant down to the top of the lower layer of frictional resistance.

Similarly we may consider a circular wind system within an area which is situated completely in one hemisphere. If the circulation is *contra solem* the surface layers are driven away from the centre and a field of solenoids is built up which results in a current in the direction of the wind. If the circulation is *cum sole* the light surface water will be carried towards the centre and a density distribution is brought about which gives rise to a convection current circulating *cum sole*.

These considerations show the character of the currents which may be produced in homogeneous and non-homogeneous water under the action of the wind, and also that conditions become much more complicated when the water is non-homogeneous. In order to undertake a complete analysis of the ocean currents one has, furthermore, to consider changes in the distribution of density, which are caused by such factors as heating and cooling, evaporation, etc. The problem becomes so complicated that at present it cannot be made the subject of any mathematical analysis, but it seems possible to follow some simple lines of reasoning which lead a step further and which give some indications of the structure of the circulations in the sea.

In the first place it is of much interest to ascertain whether any evidence is present for the existence of slope currents in a non-homogeneous sea. It is not *a priori* given that such currents are developed. As will be shown below, under the action of the wind on the surface of a channel of uniform depth running around the world, a stationary current can exist only in the absence of a slope current, and generally it is possible that the principal effect of the wind is to build up a solenoid field which gives rise to a convection current and not to bring about a piling up of the water along a boundary.

It has, however, to be borne in mind that the surface of a non-homogeneous sea is, as a rule, not horizontal. Suppose that in the upper layers the density varies horizontally but is constant at great depths and that the current is practically zero at great depths. The latter assumption involves that at great depths the isobaric surfaces are horizontal or level surfaces, and it follows that the surface of the sea shows elevations where the average density is small and depressions where the average density is great. Within a convection current the light water is accumulated on the left-hand side (in the southern hemisphere) and, therefore, the surface of the sea is higher on the left-hand side of the current. The surface, therefore, is inclined even if no slope current in the sense of Ekman is present, and in the presence of such a slope current the actual inclination is the combined effect of the distribution of density and the piling up of the water.

By means of very precise levelling the variations of the sea-level along coasts can be determined. By comparing the results with the corresponding variations which can be derived from the distribution of density, it should be possible to decide if this distribution is alone responsible for the variation, or if in addition a piling up effect has to be considered. Some results of highly precise levelling in the United States and Central America have been discussed by Avers (1927). Between Colon and Panama a difference in sea-level of 17·8 cm. has been found, the level being highest on the Pacific side. By means of the observations of the 'Carnegie' in the Caribbean Sea and the Gulf of Panama, a corresponding difference of about 35 cm. is found, supposing the pressure at a depth of 3000 m. to be the same in both seas. If these figures can be brought in relation to each other, they would indicate that the difference of level, which should be expected because of the difference in density, has been reduced. Such a reduction would be brought about if the water were piled up in the Caribbean Sea and drawn away from the coast in the Gulf of Panama.

Avers, furthermore, points out that the sea-level increases from south to north both along the Atlantic and Pacific coasts. Along the Atlantic coast an increase of 31 cm. is recorded from St Augustine, Florida, to Portland, Maine, while along the Pacific coast an increase of 34 cm. is found between San Pedro, California, and Seattle, Washington. The sea-level is from 49 to 59 cm. higher at the Pacific coast than at the Atlantic. It seems possible that the increase along the Atlantic coast can be associated with variations in the density of the water, but observations which are suitable for a test are not available. It may, however, be pointed out that to the north of Portland, Maine, the sea-level must sink, if the height depends upon the density of the water, because in that region the average density increases rapidly to the north. Along the Pacific coast the increase in the height of the sea-level cannot be attributed to a variation in the density, since this, according to the observations of the 'Carnegie,' should rather tend to cause a decrease from south to north. It is, on the other hand, not very probable that the prevailing winds will cause a considerable piling up of the water at the two coasts, because the general directions are such that the surface water is drawn away. The results of these levellings, therefore, throw no more light upon the question of the relative importance of the distribution of density and the piling up effect of the wind. Apart from the result, that the sea-level is higher along the Pacific coasts than along the Atlantic, which can be brought into agreement with the distribution of density, the introduction of the results of the levelling has raised new questions instead of solving old ones.

There exist, on the other hand, observations which indicate that in the oceans the piling up effect of the wind is negligible. The observations of the International Ice Patrol around the Grand Banks of Newfoundland have been used for constructing charts, showing the topography of the surface relative to some level at which the velocity of the current presumably must be small. From these topographic charts the currents at the surface can be derived, and since the tracks of icebergs have shown a remarkable agreement with the computed currents, the latter must closely represent the actual flow of the water. It is unnecessary to assume the existence of a slope current, and thus no indication of a piling up of the water exists.

A still more striking example is found in the Strait of Florida where, according to Wüst (1924), the currents which are computed from the distribution of density agree perfectly with the measurements by Pillsbury. There the sea-level rises 30 cm. over a distance of 40 km. in a direction at right angles to the coast. This very big rise over a short distance clearly shows the importance of the distribution of density to the inclination of the sea-level. We must, however, leave open the question as to the possible piling up effect of the wind and the existence of slope currents, and we shall proceed to a discussion of stationary wind currents in non-homogeneous water.

Let us again consider the case of a channel running all around the earth in the southern hemisphere. As a primary effect of the wind the light surface water will, as previously stated, be transported to one side of the channel, a field of solenoids will be produced and a convection current in the direction of the wind will commence. This convection current must gradually become stronger as long as the pure drift current continues to transport the light surface water across the channel. Stationary conditions can be reached only when all transversal motion stops, because any transversal motion must cause changes in the distribution of the density, if no other factors tend to maintain a certain distribution.

It is easy to find the conditions which must be fulfilled if stationary conditions are to exist. The equations of motion have in the stationary case the form:

$$\left.\begin{aligned} -\alpha\frac{\partial p}{\partial x} + 2\omega\sin\phi\, v_y + \frac{d}{dz}\left(\nu\frac{dv_x}{dz}\right) = 0 \\ -\alpha\frac{\partial p}{\partial y} - 2\omega\sin\phi\, v_x + \frac{d}{dz}\left(\nu\frac{dv_y}{dz}\right) = 0 \end{aligned}\right\}, \qquad \ldots\ldots(1)$$

where α represents the specific volume, p the pressure, ν the coefficient of eddy viscosity and v the velocity. The positive z-axis is directed downwards. Placing the positive y-axis in the direction of the channel and the x-axis at right angles to the channel we have:

$$-\alpha\frac{\partial p}{\partial x} = f(z), \quad -\alpha\frac{\partial p}{\partial y} = 0. \qquad \ldots\ldots(2)$$

Assuming, furthermore, that the wind blows in the direction of the channel, the boundary condition at the surface takes the form

$$\left(\nu\frac{dv_x}{dz}\right)_0 = -T_x, \quad \left(\nu\frac{dv_y}{dz}\right)_0 = -T_y, \qquad \ldots\ldots(3)$$

where T represents the tangential stress of the wind.

Conditions can be stationary only when no transport takes place across the channel, or when $v_x = 0$ at all levels. From equations (1) and (3) it follows that this condition is fulfilled when

$$\nu\frac{dv_y}{dz} = -T = \text{constant.}$$

Since the coefficient ν is always positive, it follows that the velocity must decrease at all depths, and since it is improbable that ν increases with depth it also follows that the velocity decreases more and more rapidly with increasing depth. Furthermore, the pressure gradient and the velocity must be zero at the bottom. If the velocity at the bottom differs from zero the influence of the friction at the bottom must give rise to a transversal current, in which case the original condition that v_x shall be zero at all levels cannot be fulfilled.

The solution which gives stationary conditions can be written in the following form if h is the depth to the bottom:

$$-\alpha\frac{\partial p}{\partial x} = f(z); \quad z = h, f(z) = 0; \quad -\alpha\frac{\partial p}{\partial y} = 0;$$

$$v_y = -\frac{1}{2\omega\sin\phi}f(z); \quad v_x = 0;$$

$$\nu\frac{dv_y}{dz} = -T.$$

The condition that the pressure gradient shall be zero at the bottom leads, as already stated, to the conclusion that a slope current cannot exist, because within the slope current the gradient remains unchanged from the surface to the bottom.

It can easily be shown that such currents, as the above solution demonstrates, are not met with in the sea. In order to do this it is necessary to introduce some function which shows the relationship between the tangential stress of the wind and the wind velocity. According to Ekman's and Taylor's investigations we have approximately

$$T = 3{\cdot}2 \times 10^{-6}\,(W - V)^2,$$

where W is the velocity of the wind and V the surface velocity of the water. The latter is usually so small compared with the former that it can be disregarded, but in the present case it has to be considered. Furthermore, it should be noted that with given values of T, and ν_0 the coefficient of eddy viscosity at the surface, the smallest surface velocity is reached if the velocity is a linear function of depth, which means that the eddy viscosity is constant. This follows from the assumption that the eddy viscosity does not increase with depth. Consequently we can find a minimum value of the surface velocity when we introduce

$$-T = \nu_0 \frac{V_{\text{min.}}}{h},$$

where h is the depth. We obtain:

$$3{\cdot}2 \times 10^{-6} (W - V_{\text{min.}})^2 h - \nu_0 V_{\text{min.}} = 0.$$

In the first place, it is seen that we always find two values of $V_{\text{min.}}$, one which is smaller than W and one which is greater, but only the former is of interest. It is also seen that the velocity of the current at the surface approaches the wind velocity asymptotically when the depth increases towards infinity.

In order to show the surface velocities which may exist under the above conditions, numerical values have been computed. The values of ν_0 at different wind velocities are those which have been given by W. Schmidt. We find the following minimum values of the surface velocity (in cm./sec.) at given wind velocities and at given values of the depth of the channel:

Depth m.	Wind velocity, cm./sec.		
	5×10^2	10×10^2	15×10^2
	Coefficient of eddy viscosity		
	110	430	950
50	32	38	40
100	57	66	69
500	180	206	259
1000	223	332	404
5000	346	599	808

Hence, if the wind velocity is 10 m./sec. we should obtain a surface velocity of at least 3·32 m./sec. if the depth were 1000 m. and of 5·99 m./sec. if the depth were 5000 m. These results are quite unreasonable, and the obvious conclusion is that stationary currents, which are due to the effect of the wind on the distribution of density, do not exist in the oceans.

Ekman has already drawn this conclusion, and the above computation has only been made in order to emphasize a well-known feature. Ekman has, furthermore, pointed out that stationary currents can exist only if they are directed along the parallels of latitude and when the depth is constant. The latter conditions are never fulfilled in the sea and, therefore, no stationary currents can exist.

The circumstance which must be emphasized here, however, is that a pure drift current must be present unless:

$$\nu_0 \frac{dv'_x}{dz} = -T_x, \quad \nu_0 \frac{dv'_y}{dz} = -T_y,$$

where v' represents the velocity of the convection current. The slope current is independent of depth and need not be considered in this connection. This condition leads to a decrease of the velocity near the surface of an order of magnitude which is never observed in the open ocean, where the decrease very often is small in the surface layers and greater at some intermediate depth. Hence, a pure drift current must always be present when a wind blows, and within this a transport of water takes place, which is directed 90° *cum sole* from the direction of the wind. Fjeldstad (1930) has shown that the total transport can be derived from the wind resultant and, therefore, all the irregularities in the wind systems need not be considered. Because of this transport vertical circulations must be developed, partly because of the limitations of the oceans and partly because of convergences and divergences in the wind systems.

The vertical circulations, which are maintained by the wind systems, would lead to changes in the distribution of density, which, as previously shown, would further develop the solenoid field which the wind builds up, and thus further increase the velocity of the convection currents. Since the distribution of density in the oceans appears to have a stationary character, it follows that the effect of the vertical circulation, which is caused by the wind, must be counteracted by other factors which influence the distribution of density. The great importance of these other factors should thus be to maintain a certain distribution of density and, therefore, when considering the total development of the ocean currents, they must be given the same weight as the effect of the wind. These factors also contribute to the development of vertical circulations, especially because cold and heavy water sinks in high latitudes.

It has been shown that vertical circulations probably exist because of the action of the wind, and several systems of this nature are well known. The so-called "upwelling" along the west coasts of Africa and America result from the action of the wind. The convection currents along these coasts are directed such that heavy water is accumulated along the coast but no vertical component would be present if the prevailing wind had not a component along the coast, which caused a transport of the surface layers away from the coast.

Little attention has been paid to other systems of vertical circulation, but a very interesting example is found within the current around the Antarctic Continent. This current carries two typically different water masses, the Antarctic and the sub-Antarctic water (Clowes, 1933). These two water masses are separated by a boundary surface which at sea-level is recognized as the Antarctic Convergence or the Antarctic Ocean Polar Front in the terminology of the German oceanographers. The boundary surface between the two water masses takes in this case the place of the coast and makes possible a vertical circulation within the Antarctic water. Before dealing with this circulation it is necessary to consider the Antarctic Convergence more closely.

Fig. 1 gives in the lower part a section of the density of the water along the meridian 30° W according to the Discovery observations. The boundary surface between the Antarctic and the sub-Antarctic water masses is indicated by a dashed line, and this boundary surface reaches sea-level in about latitude 50° S, where the Antarctic Convergence is situated. It is seen that the light sub-Antarctic water covers the heavy Antarctic water in the form of a wedge. In the upper part of the figure the inclinations of the sea surface and the 1000 decibar surface, relative to the 3000 decibar surface, are shown. Both surfaces are inclined from north to south and the current is directed towards the east both within the sub-Antarctic and the Antarctic water. The inclination is much greater to the north of the convergence and, therefore, the easterly current is much stronger on the northern side. These features are in agreement with the theoretical conclusions as to the character of the distribution of density and the flow of the water within two neighbouring water masses of different density (see Defant, 1929, p. 103), but they do not explain why such a boundary surface exists within the easterly circumpolar current. It seems obvious that no discontinuity in the variation of the density would exist if the direction of the current were due east in all latitudes and the occurrence of the convergence must, therefore, be associated with the presence of north-south components.

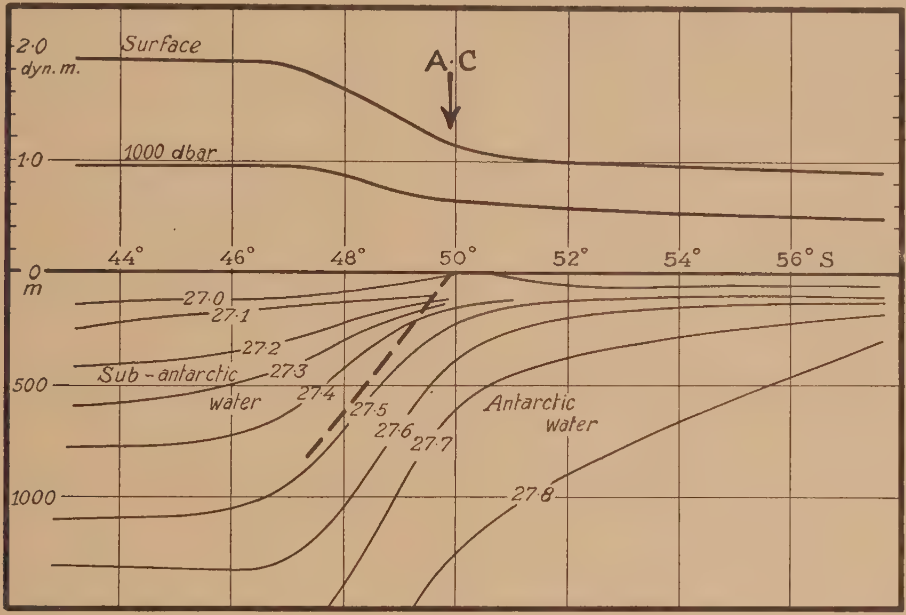

Fig. 1. Vertical distribution of density (σ_t) and inclination of the sea surface and the 1000 decibar surface, relative to the 3000 decibar surface, between latitudes 42° and 58° S in the Atlantic Ocean along the meridian 30° W.

Two factors may contribute to the development of a component towards the north within the Antarctic water: in the first place the prevailing westerly winds, and in the second place the supply of water of low salinity owing to the melting of the pack-ice. The pack-ice is, however, carried towards the north by the wind, and thus the action of the wind seems to be the principal factor which causes a flow of the surface layers to the north.

Westerly winds prevail within the regions of both the sub-Antarctic and the Antarctic waters. The wind is not blowing permanently from the west, but when considering the effect of the wind it is, as already mentioned, sufficient to take the wind resultant into account. Between latitudes 40 and 65° S the wind resultant is generally from the west, and between these latitudes a pure drift current must exist which transports the surface layers towards the north. The question arises whether the wind resultant from the west and, therefore, the transport varies with latitude. The wind observations from the southern part of the South Atlantic are too scanty to allow a definite answer, but the available data point in the direction that in summer the strongest westerly winds are met with between 50 and 60° S. This is, for instance, evident from Köppen's chart which has been reproduced in Shaw's *Manual of Meteorology*, Vol. II. This would mean that we have a great transport of water to the north between 60 and 50° S and a smaller transport north of 50° S and that, therefore, a convergence in the northward transport exists at about 50° S. This convergence must take place over a wide belt, since the change in the wind resultant must be gradual, but it may give rise to the development of a discontinuity in the ocean. Two factors may contribute to such a development: the tendency to the conservation of the angular momentum, and the tendency to a minimum consumption of eddy energy.

Thus, it seems possible that the Antarctic Convergence in the South Atlantic Ocean, which in summer is found in about 50° S, is due to a convergence in the pure drift current. Similar conditions may exist in the southern Indian and Pacific Oceans, but in the Drake Passage, where the convergence is met with in about 60° S, the location must depend upon other circumstances. This great displacement to the south may be due to the fact that the easterly current, which carries both the sub-Antarctic and the Antarctic waters, is forced through the relatively narrow passage.

All these questions deserve a closer examination, but for the present purpose it is sufficient to state that the convergence exists and that within the Antarctic water the surface layers must be transported to the north by a pure drift current. Since the westerly winds are dominant around the Antarctic Continent, the transport must take place in all longitudes. If, however, this is the case, a compensation current must carry water back to the south at some deeper level. The level at which this return flow takes place can be found only by examining the hydrographic conditions in the area in question.

An examination can now be undertaken thanks to the work of the Discovery Expeditions which have accumulated a great number of observations from the Drake Passage, the Scotia Sea and the South Atlantic Ocean. By means of the published data (1930, 1932) it is possible to construct vertical sections in these areas, and through the courtesy of Dr Kemp unpublished observations from a section along meridian 75° W, in the Pacific Ocean, have also been placed at my disposal. Six temperature and salinity sections have been constructed, and in addition sections showing the vertical distribution of oxygen and phosphate have been prepared when observations have been available. The positions of the sections are shown in Fig. 2 in which they are numbered I–VI.

In considering these sections we shall begin with the most westerly, section I (Figs. 3 and 4) along the meridian 75° W in the Pacific Ocean, to the west of Drake Passage. The observations were taken by the 'Discovery II' in November, 1931. The Antarctic Convergence is found at the surface in about 60° S. The downwards bend of the isotherms to the north of 60° S indicates sinking motion of the water, and the salinity section shows that there the origin of the Antarctic intermediate current must be sought. From the salinity diagram it seems as if the water which has left the surface continues to the north, but the temperature section gives a different picture. North of the convergence the isotherms bend towards the south and a tongue of water with temperature higher than 2° extends past latitude 64° S between the depths of 400 and 1500 m. This distribution of temperatures indicates that between these depths the current has a component which carries back to the south part of the water which has been transported to the north by the pure drift current. To the north of the convergence and below the Antarctic intermediate current, processes of mixing seem to take place, and through this mixing the salinity of the sinking water increases and the temperature decreases. The returning current, which is composed of Antarctic water and deep water, therefore has a greater density than the water of the pure drift current, but before it again reaches the surface it is diluted by melting water from the ice and by precipitation, and thus a further development of the solenoid field is prevented.

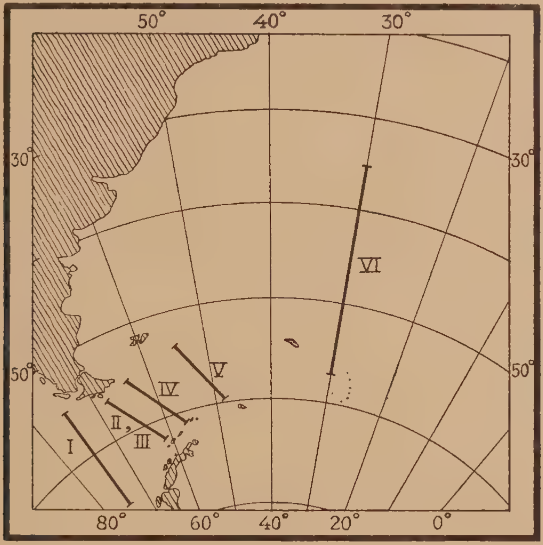

Fig. 2. Chart showing the location of the vertical sections.

It seems, however, that only part of the water which has been transported to the north returns again to the south. In order to complete the compensation, the deep water below 1500 m. must also have a component towards the south, and finally the bottom water appears to have a component to the north. Below the vertical circulation of the upper layers, we, therefore, must have a similar circulation, which, when looking in the direction of the current, rotates clockwise, while the circulation of the upper layers rotates counter-clockwise. The possible circulations are indicated in the sections by means of arrows. In this and the following sections the arrows were first plotted by means of the temperature distribution and afterwards entered on the other diagrams.

The author is aware that great caution must be exercised when drawing conclusions as to presence of currents from tongue-like distributions of oceanographic elements. Later, other features will be discussed which confirm our conclusions, but now we shall proceed with a discussion of the other vertical sections.

Figs. 5–10 show the sections II and III through the Drake Passage, one made by the

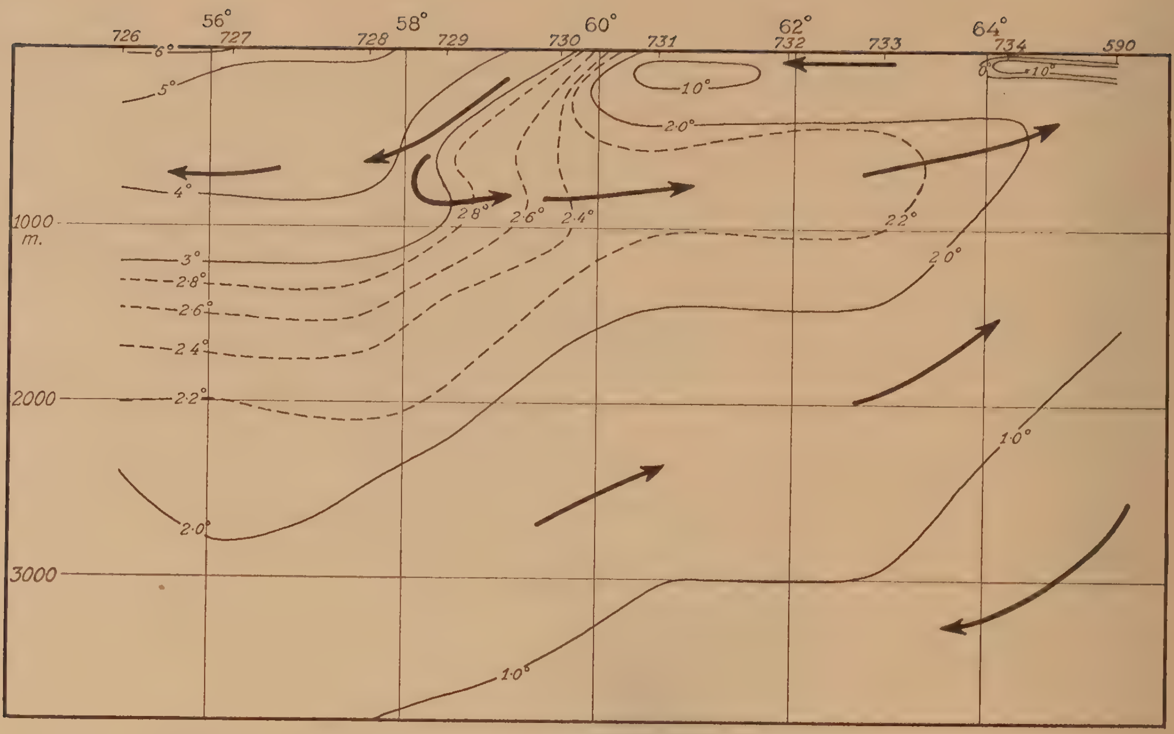

Fig. 3. Section I. Distribution of temperature (° C.).

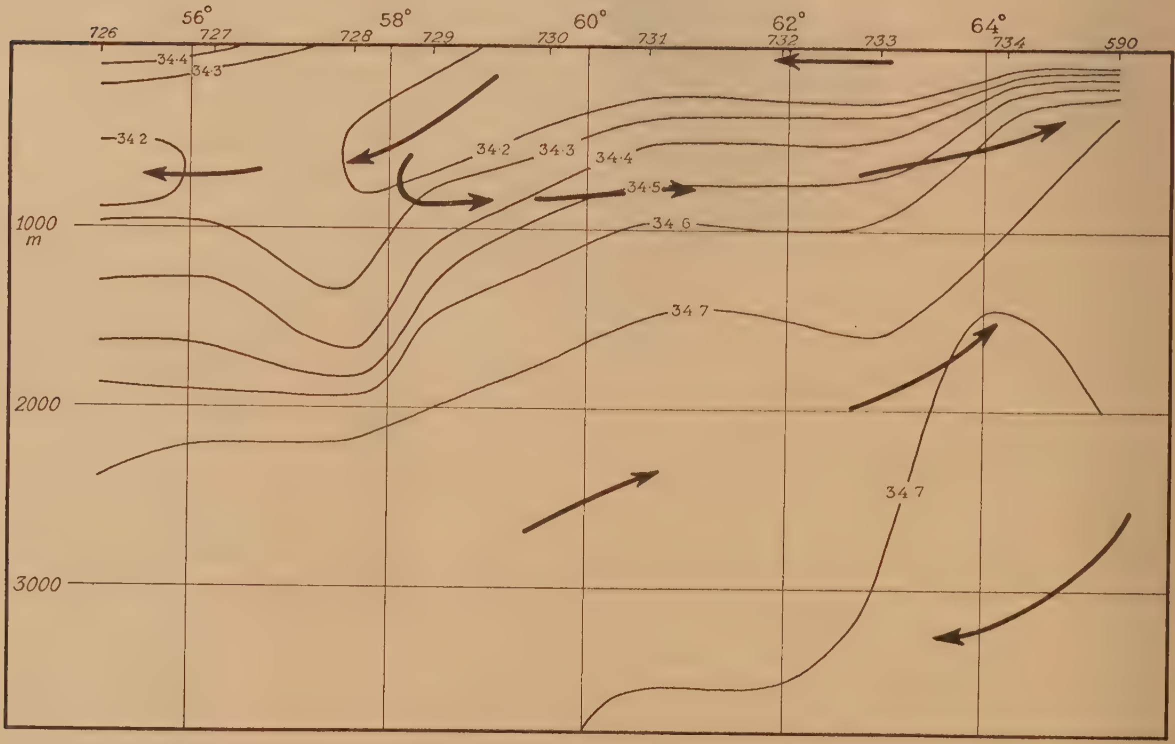

Fig. 4. Section I. Distribution of salinity (°/₀₀).

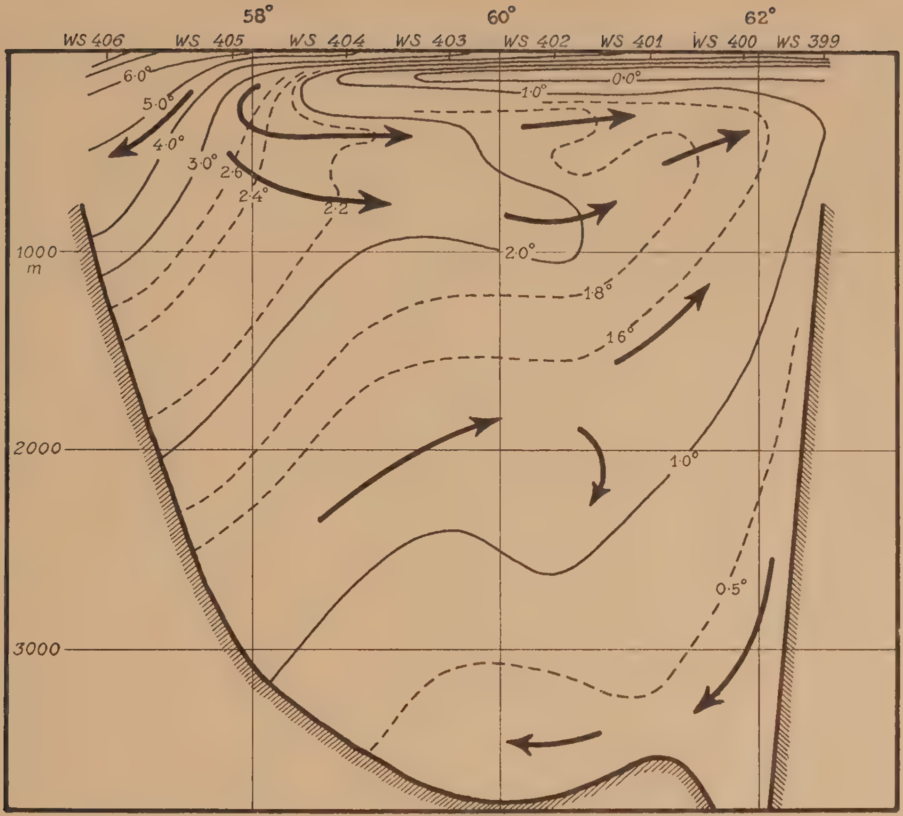

Fig. 5. Section II. Distribution of temperature (° C.).

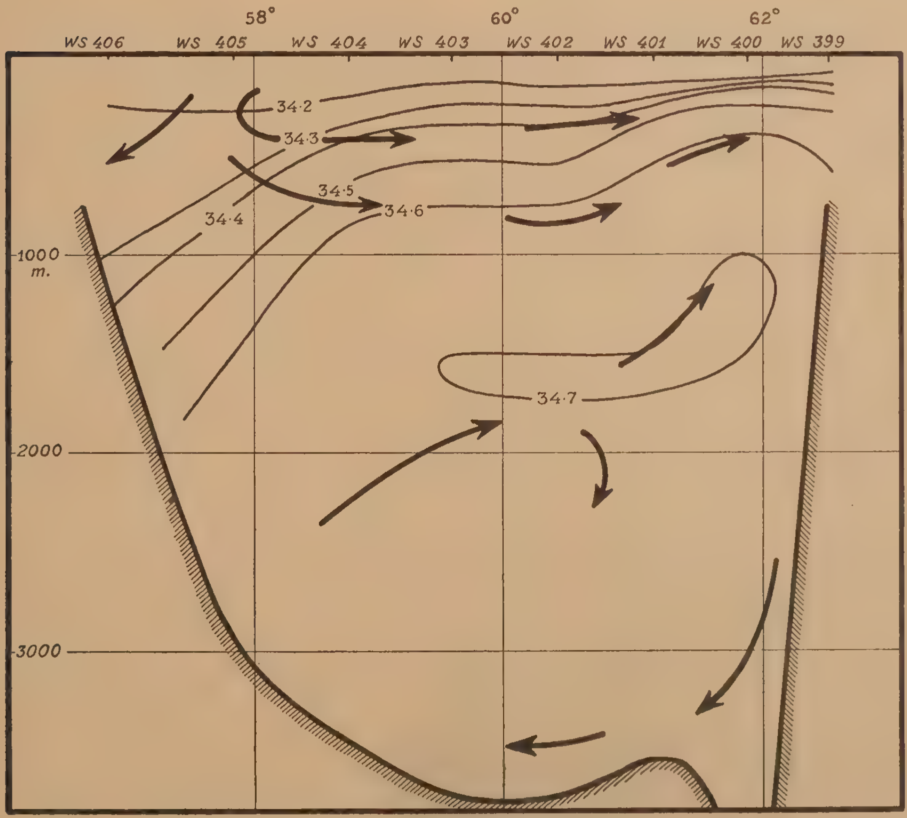

Fig. 6. Section II. Distribution of salinity (°/₀₀).

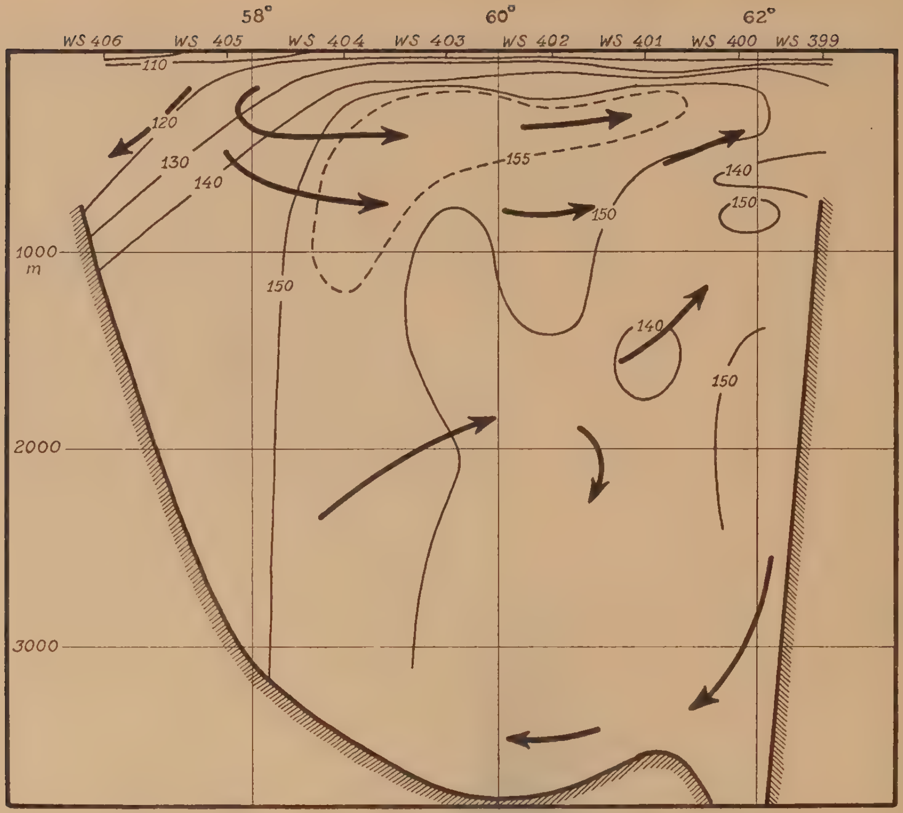

Fig. 7. Section II. Distribution of phosphate (P_2O_5 mg./m.^{3}).

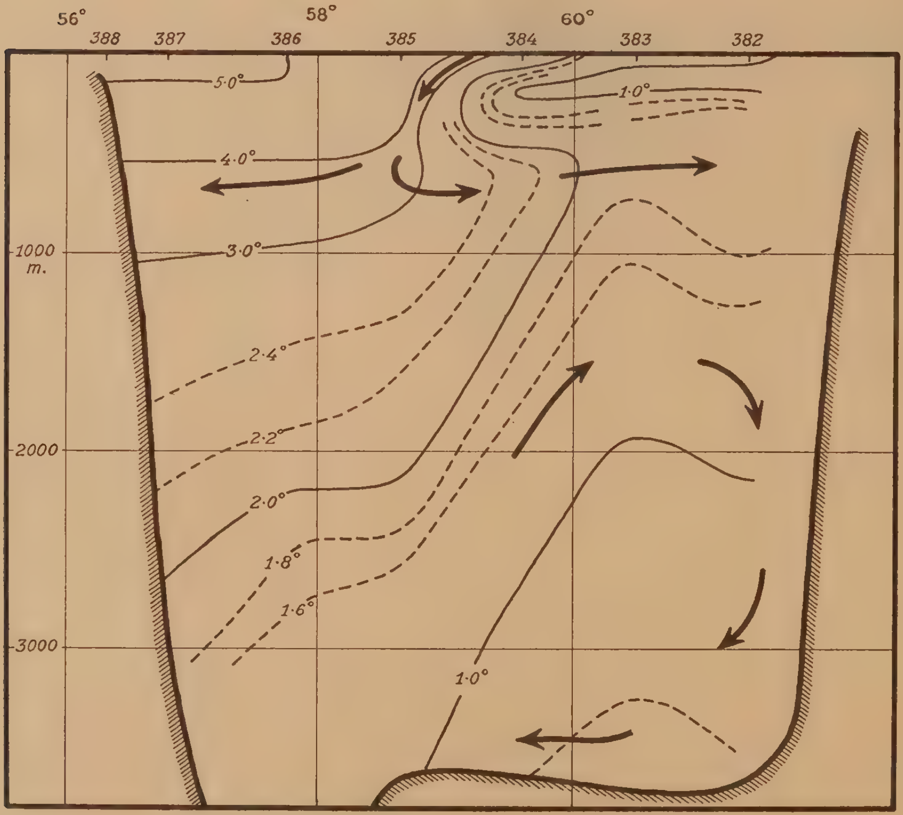

Fig. 8. Section III. Distribution of temperature (° C.).

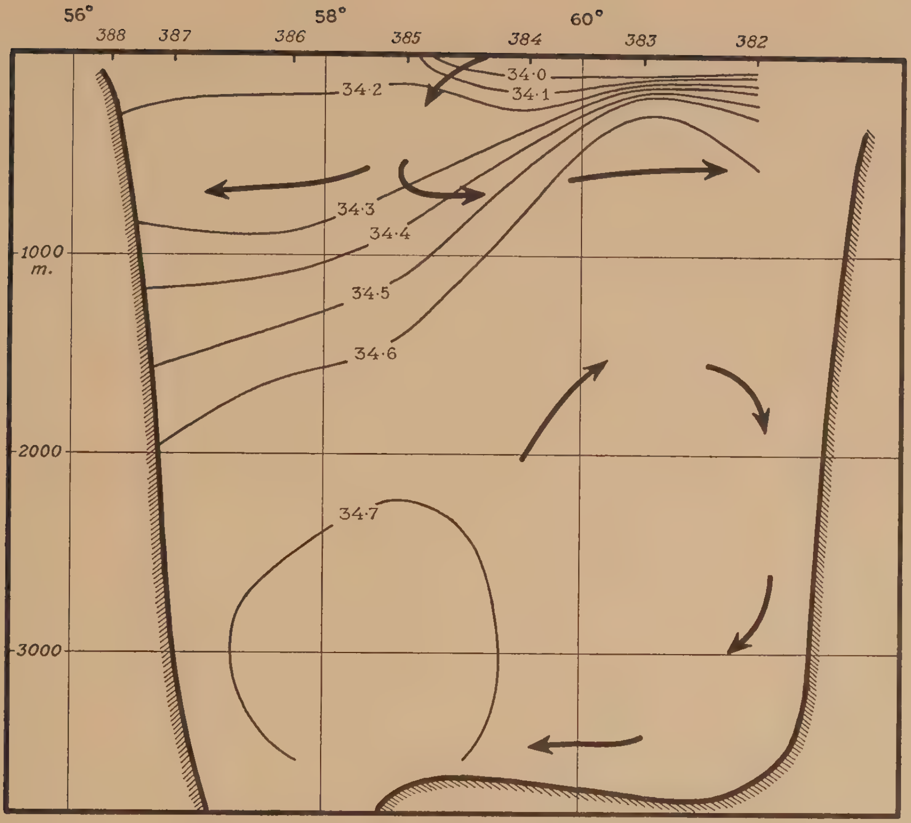

Fig. 9. Section III. Distribution of salinity (°/$_{oo}$).

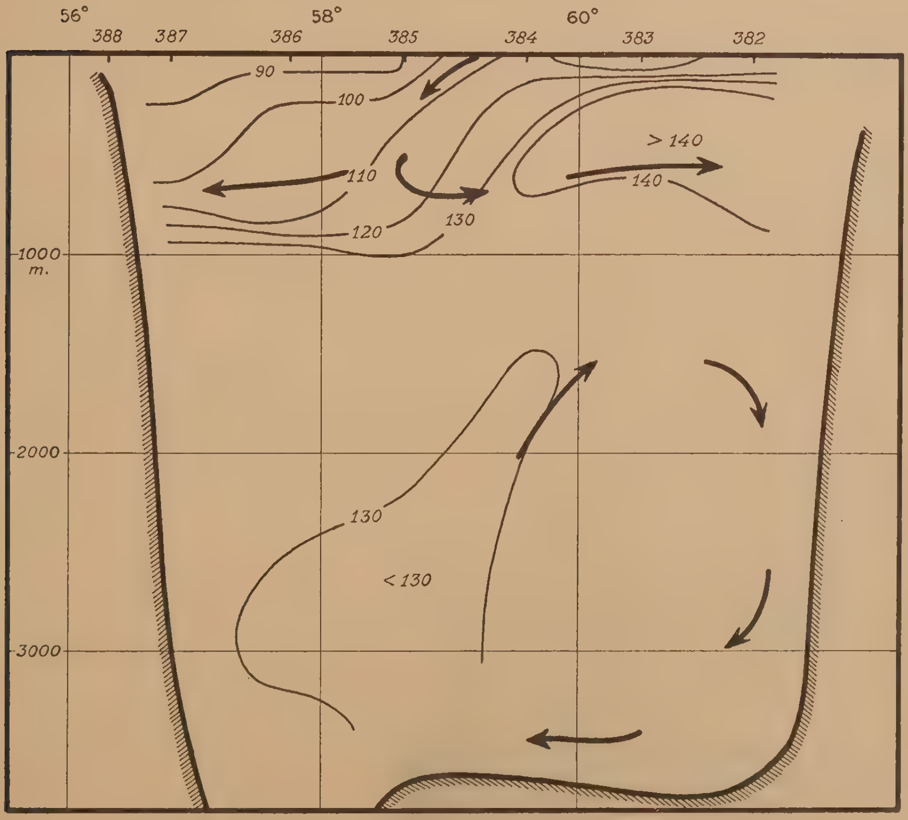

Fig. 10. Section III. Distribution of phosphate (P_2O_5 mg./m.^{3}).

'William Scoresby' at the end of February, 1929, and one made by the 'Discovery II' in the middle of April, 1930. In the two years the conditions were rather different, but in both years the tongue of water with high temperature was present. In 1929 it reached almost from the northern to the southern side of the Passage, but in 1930 it extended only from the middle of the Passage to the southern side. In 1929 the tongue appeared to be divided, indicating that the southward flow took place at approximately the levels of 400 and 900 m., except in the most southerly region where the two branches appeared to unite. In 1930 only one tongue with an axis at about 500 m. was present. In the southern part of the Passage the 1° isotherm shows in both sections a downwards bend, which perhaps indicates that part of the deep water which flows south turns back and joins with the north-flowing bottom water.

In both sections the distribution of salinity indicates that on the northern side of the convergence the intermediate Antarctic current flows with a northerly component at depths between 400 and 700 m. The salinity of the north-flowing water is between 34·2 and 34·3 $^{\circ}/_{\circ\circ}$, while the surface salinity of the upper layers is lower. The salinity of the descending water must, therefore, have been increased by mixing with deep water, and such an increase, owing to mixing, appears to have still more influenced the salinity of the intermediate current which returns to the south. The water of this current has a salinity of 34·5–34·6 $^{\circ}/_{\circ\circ}$. The mixing seems principally to take place at some depth below the convergence.

Observations of phosphate are available from both years, and by means of these the vertical sections in Figs. 7 and 10 have been constructed. These show that the maximum phosphate values are found directly above or within the intermediate return current. Both the vertical and the horizontal extensions of the phosphate maxima agree remarkably well with the position of the current, and later on we shall discuss the significance of this feature.

The next section, section IV (Figs. 11, 12 and 13), lies about 300 km. to the east of sections II and III. The observations were taken by the 'Discovery II' in the middle of March, 1931. The temperature section shows features which are quite similar to those of the more western sections. To the north of the convergence we find a region of mixing within which the descending current is divided into two branches, one which continues to the north at depths of 400–700 m., carrying water of a temperature of about 4° and salinity 34·2 $^{\circ}/_{\circ\circ}$, and one which returns to the south at a depth of about 400 m., carrying water of about 2° and 34·6 $^{\circ}/_{\circ\circ}$. North of the convergence the region of mixing appears to reach to a depth of about 1500 m. It is interesting to note that the temperature distribution in section II shows features which are intermediate between those of sections I and IV.

Below the intermediate currents a vertical circulation of the deep water again appears to be present. The downward bend of the 1° isotherm which was seen in sections II and III is also conspicuous in section IV.

No phosphate observations were made at section IV, but observations of oxygen were undertaken and they give a very interesting picture (Fig. 13). The Antarctic intermediate water to the north of the convergence has a high oxygen content of nearly 6 c.c./litre. On the northern side of the convergence the region of mixing is clearly seen, reaching to about 1500 m. The water of the intermediate return current contains much less oxygen, i.e. less than 4 c.c./litre. Within the deep water we find a small oxygen content in the northern part, but the ascending deep water contains more, while the north-flowing bottom water shows the highest oxygen content.

Section V (Figs. 14–17) passes through the Scotia Sea. The observations were taken by the 'Discovery II' in the beginning of March, 1931. Several features are similar to those of the more western sections. Examining the temperature and salinity sections we recognize in the extreme northern part the Antarctic intermediate water of about 3° and 34·1–34·2 °/₀₀ and, in the central part of the section, the intermediate return current. This rises from about 1000 m. in latitude 54° 30′ S to about 400 m. in latitude 58° S and carries water of about 2° and 34·5 °/₀₀. One new feature is seen. In the southern part we find cold water of a temperature below 0° and of low salinity representing water from the Weddell Sea which has flowed over the ridge between the South Shetland and the South Orkney Islands.

The phosphate and oxygen sections do not extend as far north as the temperature and salinity sections because no observations of phosphate and oxygen were made at St. 653. The incomplete sections show, nevertheless, features which are quite similar to those of the sections farther to the west. The water of the intermediate return current shows high phosphate and a low oxygen content. The cold water of the Weddell Sea is rich in oxygen but contains less phosphate than the south-flowing water.

The last section, section VI (Figs. 18–21), follows the meridian of 30° W in the Atlantic and reaches from about 58° S to almost 34° S. The observations were taken by the 'Discovery II' at the end of April, 1931. The distances between the stations are great and, therefore, the horizontal scale has been reduced to one-half. This should be borne in mind when studying the section.

The north-south extension of the section VI is so great that both the Antarctic and the sub-tropical convergences are seen. The former is here situated slightly to the north of 50° S, while the latter is found at about 40° S. To the north of the Antarctic Convergence the sinking of the water and the northerly flow of the Antarctic intermediate current are clearly seen from the salinity section. After having left the upper layers the Antarctic intermediate water flows horizontally at a depth of about 400 m., but shortly before reaching the region of the sub-tropical convergence it sinks further down, to about 1000 m. in the northern part of the section. The salinity increases somewhat, from less than 34·2 °/₀₀ to nearly 34·3 °/₀₀, but the temperature remains nearly constant at 4°. The oxygen content is high, between 5 and 5·5 c.c./litre, but the phosphate content is relatively low and varies between 110 and 120 mg. $P_2O_5/m.^3$ The temperature section indicates as previously the existence of a warm intermediate return current towards the south. This current begins in the region of mixing to the north of the Antarctic Convergence and on its southwards course it rises from a depth of about 900 m. in 46° S to about 400 m. in 56° S. The water of this current is rich in phosphate,

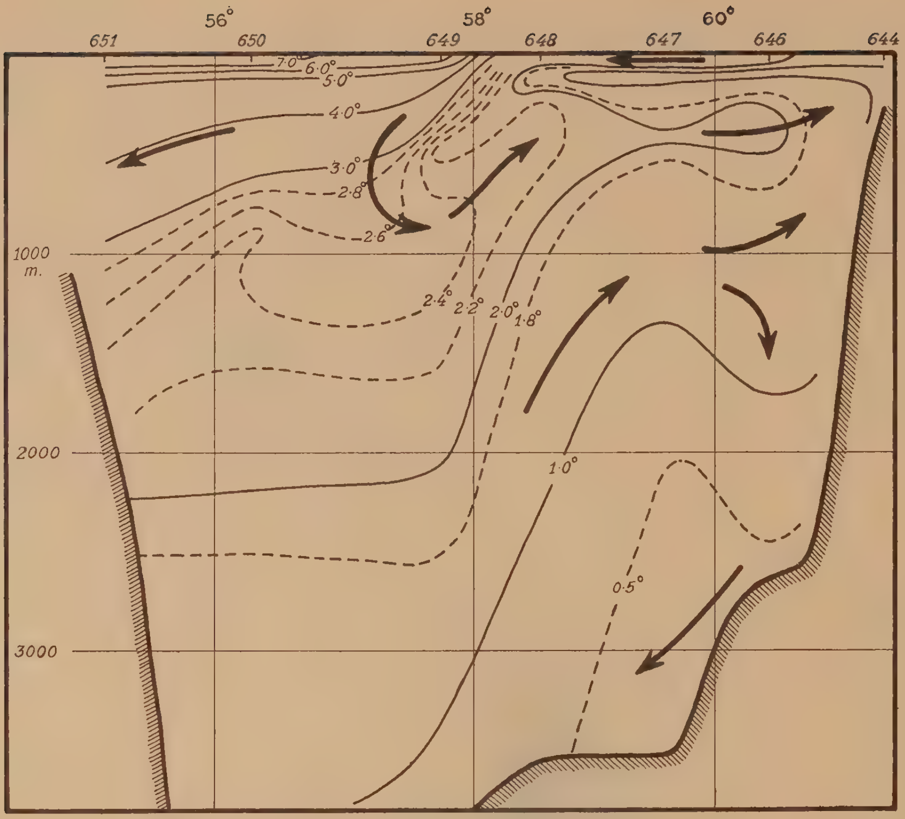

Fig. 11. Section IV. Distribution of temperature (° C.).

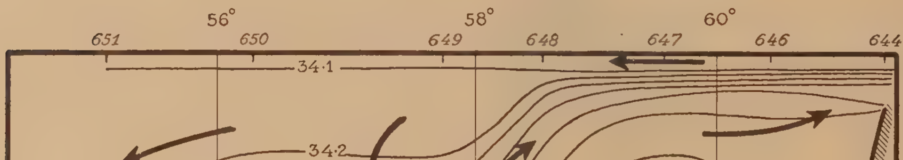

Fig. 12. Section IV. Distribution of salinity (°/₀₀).

containing 140–150 mg. $P_2O_5/m.^3$, but it contains relatively small amounts of oxygen. The lowest oxygen values, 3·8 c.c./litre, are found directly below the return current.

The deep water below the return current again appears to have a component towards the south and shows an ascending motion, while the cold bottom water from the Weddell Sea sinks and pushes to the north.

In the northern part of the section, features are met with which were not present in the Pacific and in the Drake Passage. Below the sub-tropical convergence Atlantic deep water with salinities above 34·8 $^{\circ}/_{\circ\circ}$ pushes to the south at depths between 2500 and 3000 m. This southward flow of deep water is also indicated by the bends of the isotherms at depths between 1500 and 2500 m. From the temperature and salinity sections it appears as if the water of high temperature and relatively high salinity at 500 m. in 56° S represents the last traces of the Atlantic deep water, but it must, as pointed out by Clowes (1933), be borne in mind that the general direction of the current in this region is from west and that, therefore, the water in 56° S does not come from the Atlantic but from the Pacific. A section farther to the east in the Atlantic might, on the other hand, show traces of Atlantic water in high latitudes. Near Bouvet Island salinities of 34·75 $^{\circ}/_{\circ\circ}$ were observed below 600 m. (Discovery St. 453 in 54° 06′ S and 04° E), and this water probably represents water from the Pacific which has been mixed with deep water from the Atlantic.

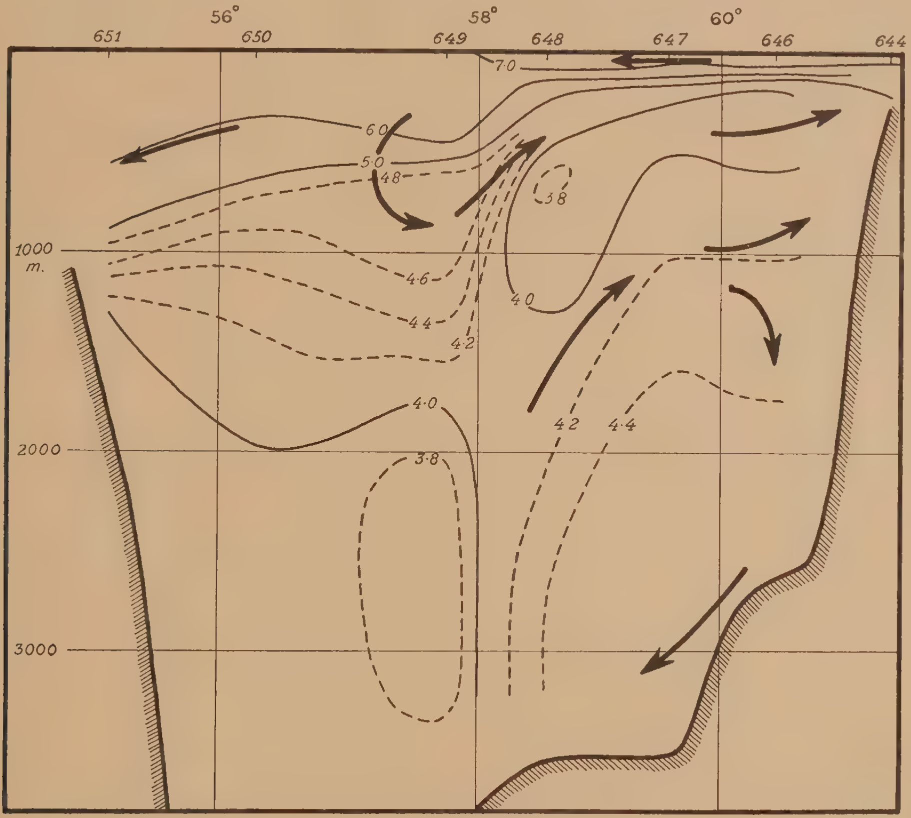

Fig. 13. Section IV. Distribution of oxygen (O_2 c.c./litre).

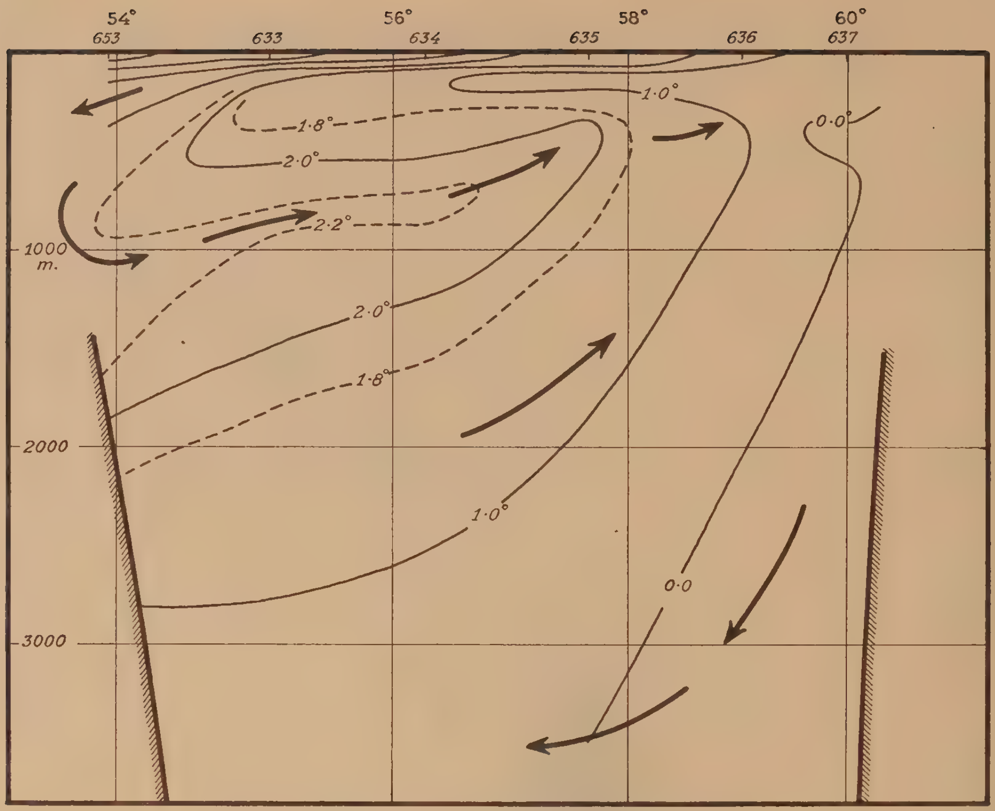

Fig. 14. Section V. Distribution of temperature (° C.).

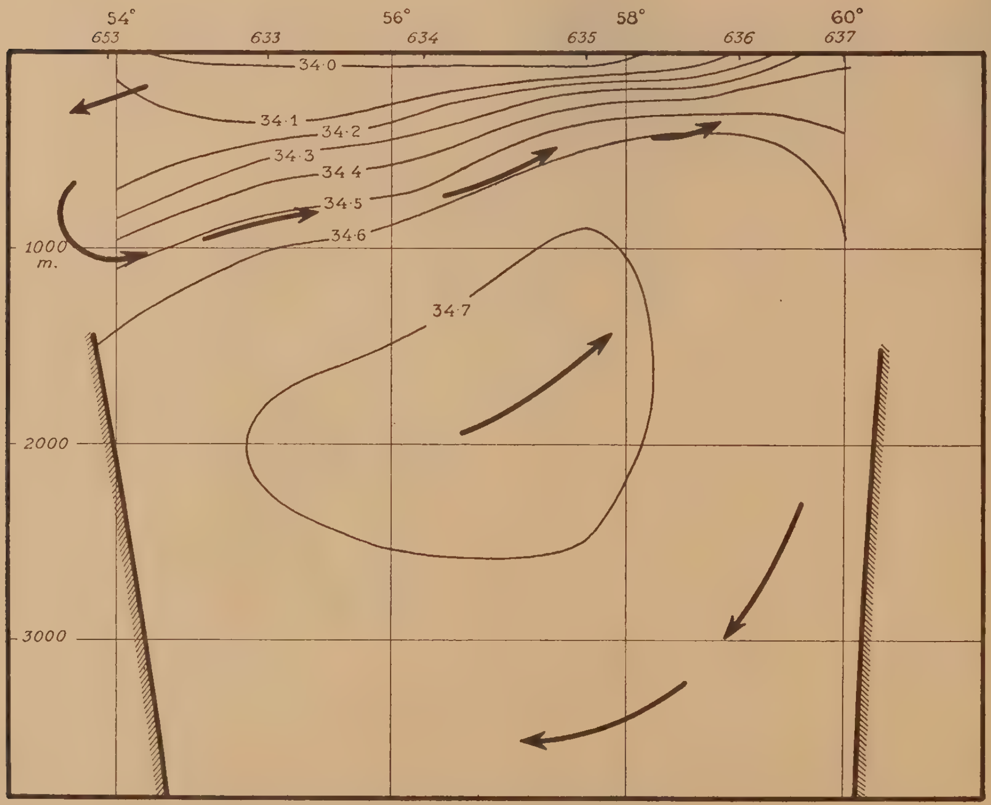

Fig. 15. Section V. Distribution of salinity (°/₀₀).

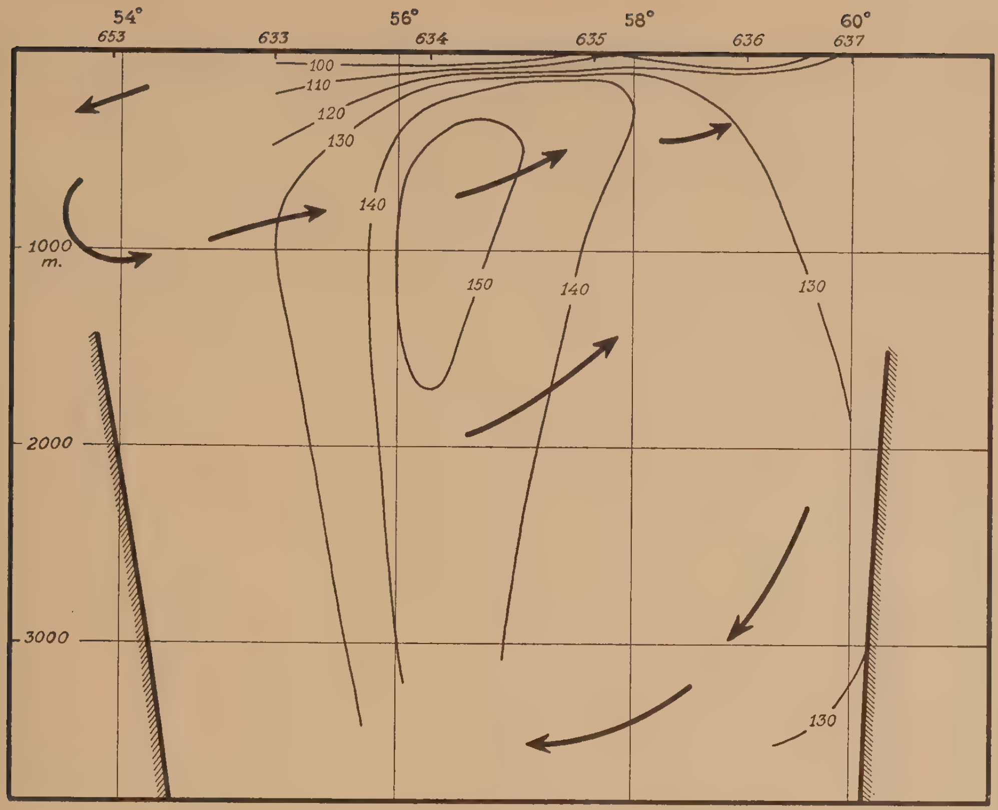

Fig. 16. Section V. Distribution of phosphate (P_2O_5 mg./m.^{3}).

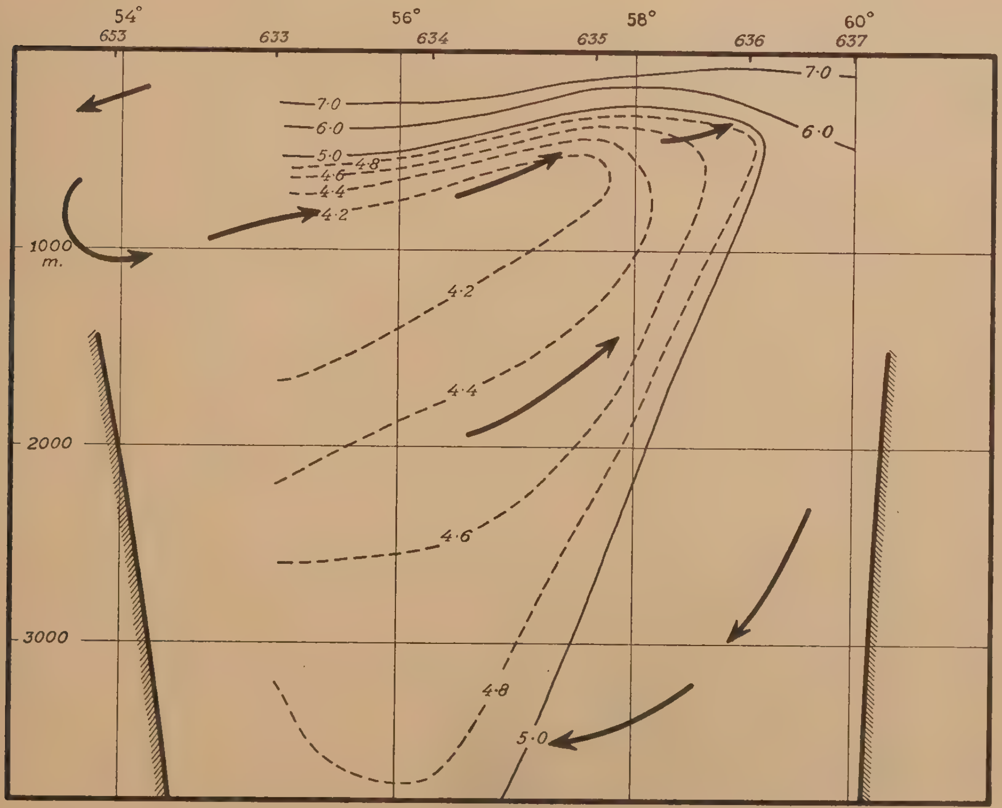

Fig. 17. Section V. Distribution of oxygen (O_2 c.c./litre).

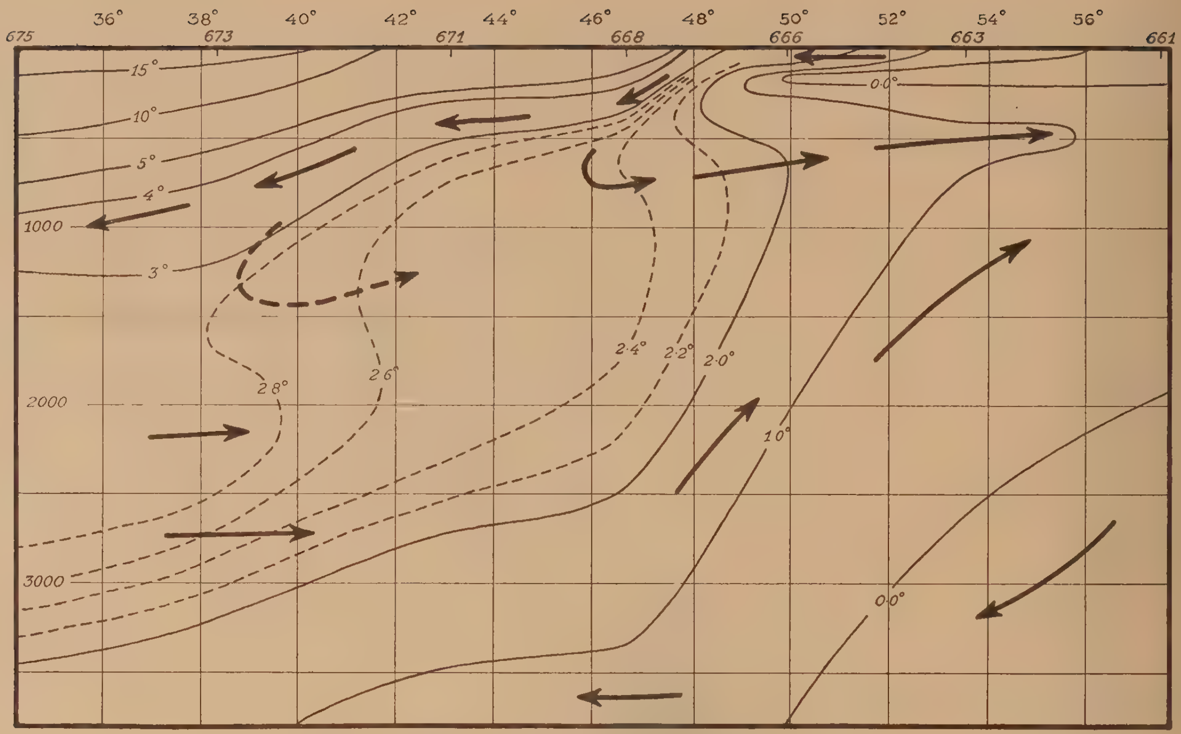

Fig. 18. Section VI. Distribution of temperature (° C.).

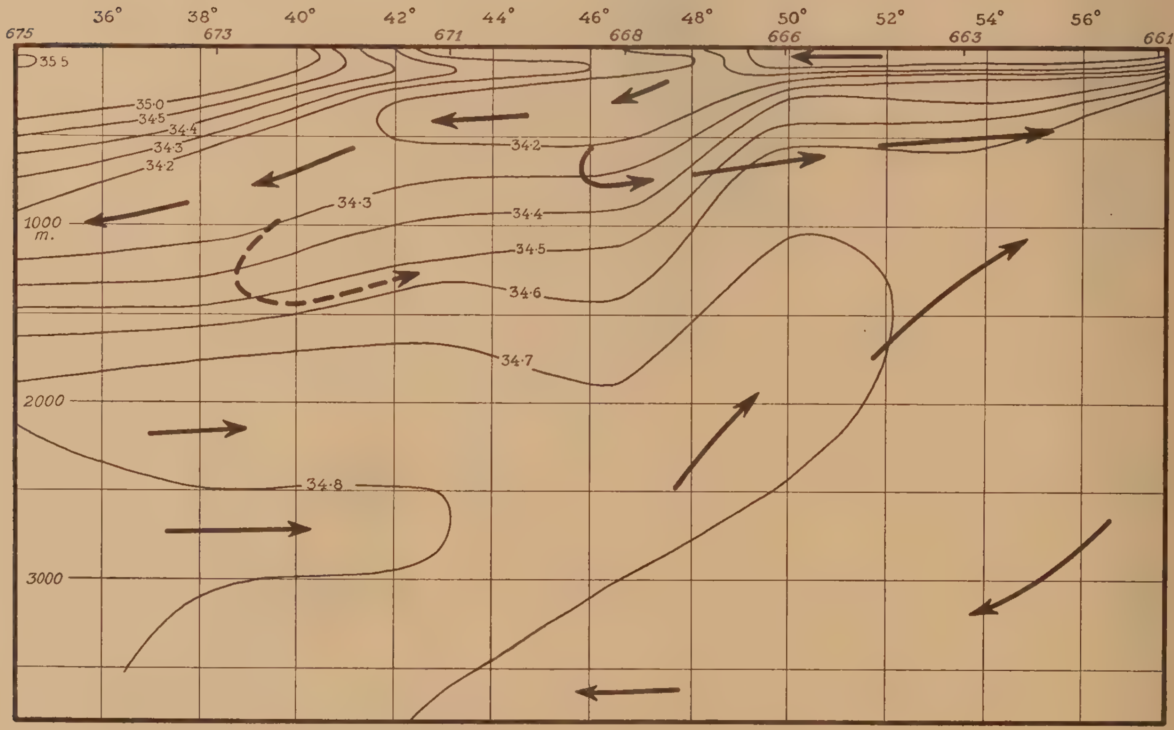

Fig. 19. Section VI. Distribution of salinity (°/₀₀).

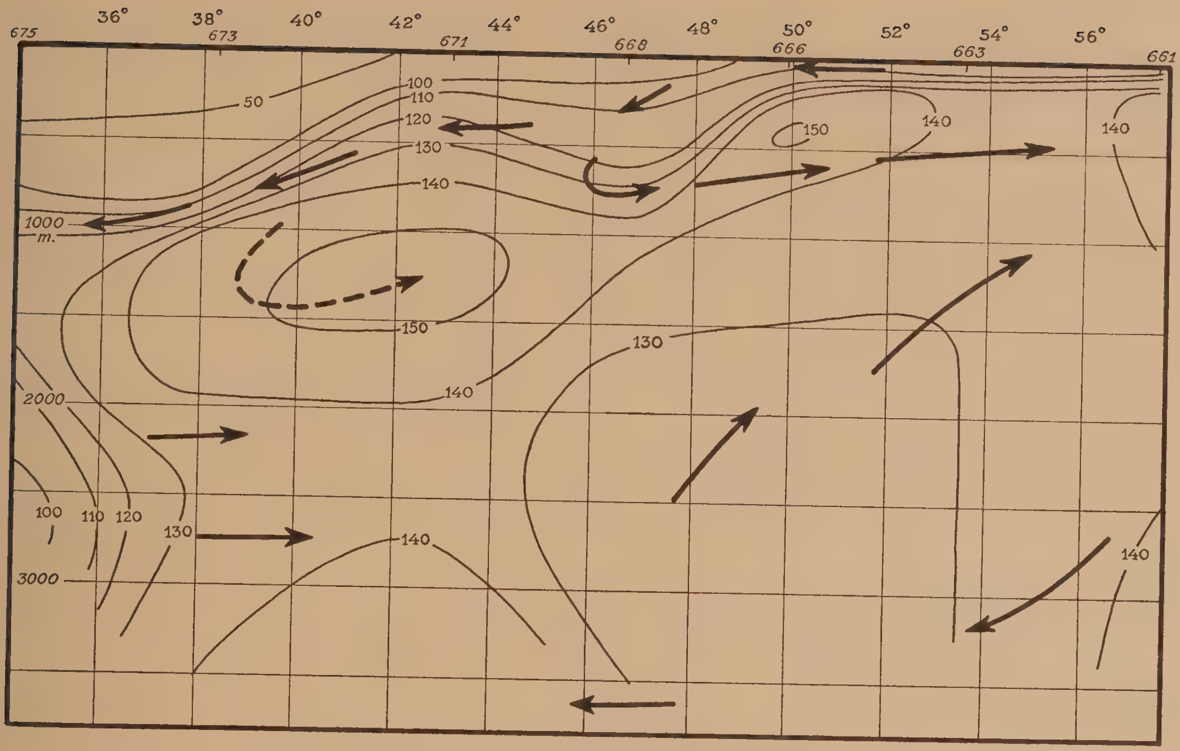

Fig. 20. Section VI. Distribution of phosphate (P_2O_5 mg./m.^{3}).

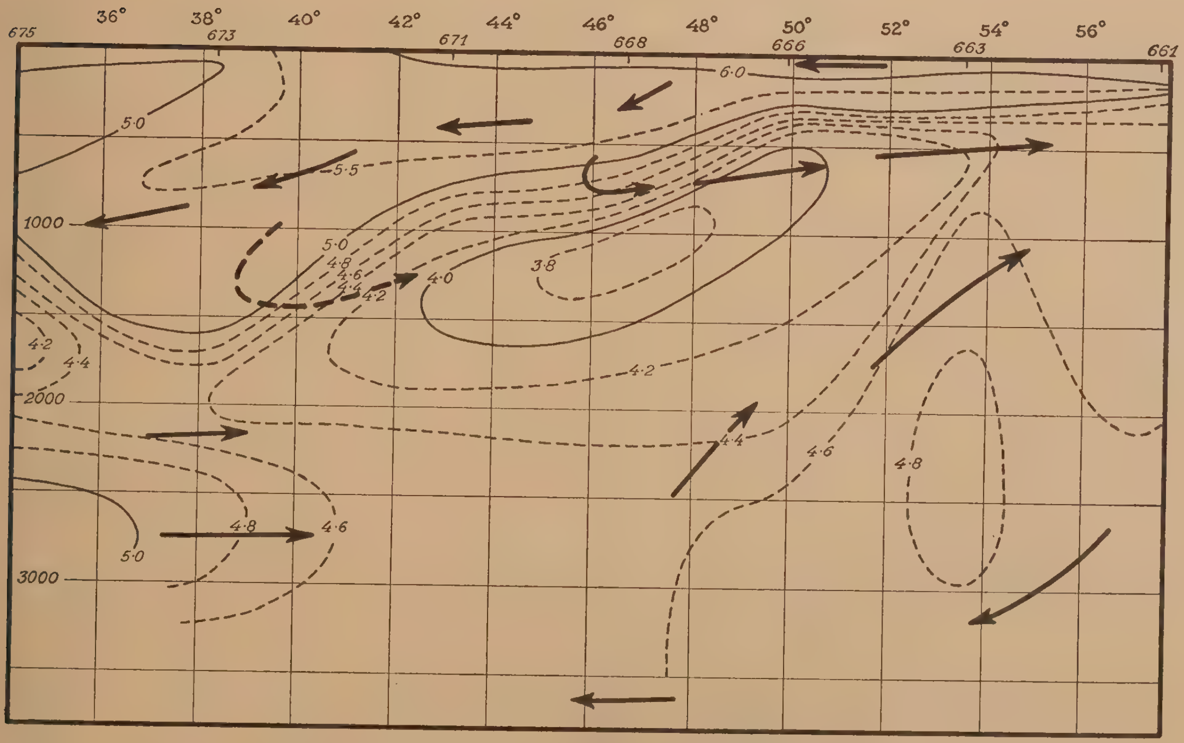

Fig. 21. Section VI. Distribution of oxygen (O_2 c.c./litre).

The sections which have been studied all show below the Antarctic water a tongue of maximum temperature at intermediate depth, which has been interpreted as showing a flow towards the south. It is, as already mentioned, necessary to exercise great caution when drawing conclusions as to the existence of a horizontal current from tongue-like distributions of oceanographic elements, but in this case the conclusion must be correct. From the *Discovery Reports* it is evident that at all stations within the body of Antarctic water an intermediate layer with water of high temperature is found, regardless of the longitude of the station. Fig. 22 shows temperature-salinity diagrams from four stations. Latitude and longitude of these stations are entered in the figure. Since all these stations from widely different areas show a similar feature it must be concluded that the intermediate layer with high temperature extends all around the Antarctic Continent. It follows that within this layer the current has a component from the north because the maximum would soon disappear on account of mixing processes if no supply of warm water from the north took place.

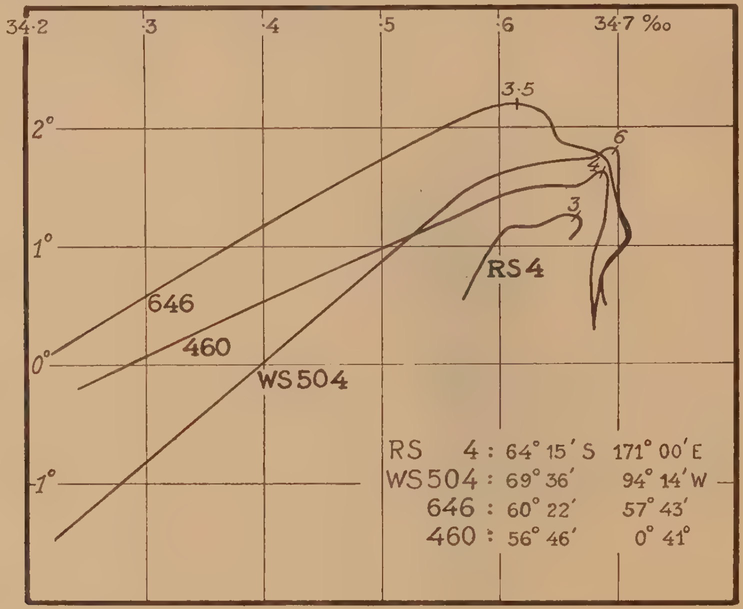

Fig. 22. Temperature-salinity diagrams at four stations around the Antarctic Continent. The numbers at the marks on the curves give the depths in hectometres.

A tongue of water of low temperature is seen in all sections, stretching towards the north at depths between 80 and 200 m. In considering this tongue it must be borne in mind that all observations were taken in summer (November to April) and that great seasonal variations occur in the upper layers. In winter an effective cooling from above takes place and the water may become intermixed and attain a uniform density to a depth of 100 m. or more, as evident from the observations at station 471 (54° 57′ S, 27° 59½′ W) on November 1st, 1930, when the temperature in the layer 0 to 100 m. varied between −1·62° and −1·77° and the salinity between 34·04°/₀₀ and 34·07°/₀₀.

In winter the pure drift current may therefore reach to depths greater than 100 m. In summer the temperature of the surface layers rises and the salinity decreases because of melting of ice and excess precipitation. The density therefore decreases and at a depth of 40 to 80 m. a sudden increase in the density is developed. In summer the lower limit of the pure drift current is found at this depth. During the summer the temperature and the salinity of the water below 80 m. increase because of admixture of the ascending water of the return current and the deep water. The observations around South Georgia show that such an increase takes place as the season advances and the feature can be explained only by admixture from below since the surface salinity decreases. The ascending motion is, however, so slow that the layer of low temperature is never completely removed in summer, but many stations are found at which only traces of the cold water are present. The layer of cold water may, therefore, be interpreted not as indicating a flow towards the north but as representing evidence of the cooling in the preceding winter.

We can now summarize our conceptions as to the structure of the circumpolar Antarctic current. Within the Antarctic water we find a vertical circulation which, when looking towards the east, rotates counter-clockwise. The surface layers are carried towards the north by the pure drift current. At the Antarctic Convergence part of the water continues towards the north as one constituent of the Antarctic intermediate current, but part is mixed with deep water and returns to the south as the warm intermediate current within the Antarctic Zone. The surface layer of the Antarctic water is very rich in plant and animal life. Within the Antarctic Zone the dead organisms sink and are decomposed and, therefore, the water of the intermediate return current shows a high phosphate content. This phosphate is carried back to the south and can begin a new cycle. The low oxygen values within or directly below the intermediate return current indicate that oxidation of organic matter takes place.

Since only part of the water which flows north returns to the south it follows that the motion of the deep water must also have a component to the south. The active cooling of the water along the Antarctic Continent leads, on the other hand, to a sinking of the water in high southerly latitudes, and the cold bottom water which is formed must flow away from the Continent towards the north. Below the upper circulation we, therefore, get a lower vertical circulation which rotates clockwise when looking towards the east. These vertical circulations are superimposed on the general easterly current, and the resulting motion has the character of complicated spirals. Within these spirals the physical properties of the water are changed in the upper layers because of heating, cooling, evaporation, precipitation or melting of ice, while in the lower layers they are changed by admixture of water from other regions. Few water particles will describe complete spirals. Some of the water, which at the surface moves north, will continue towards the north within the Antarctic intermediate current, and only part will be brought back again to the south by the intermediate return current. The water, which in high southerly latitudes must be drawn to the surface in order to replace what is carried north, consists partly of water from the intermediate return current and partly of deep water. One part of this deep water comes from more northerly latitudes, while another part belongs to the lower vertical circulation of the Antarctic.

The north-south and vertical components of this complicated circulation are shown schematically in Fig. 23. When studying this figure it must be remembered that the components of the currents at right angles to the paper (away from the reader) are much greater than any of the north-south or vertical components.

Our conception of the character of the circulation deviates considerably from that commonly accepted. Merz and Wüst (1928) consider the relatively warm and saline water at intermediate depth in high latitudes in the South Atlantic as the last traces of Atlantic deep water, which in these regions approaches the surface. Clowes (1933) has, however, shown that this water is of Pacific origin, and according to our view it belongs to the transversal circulation within the Antarctic Zone. It is true that the deep water also moves south and ascends in high southerly latitudes, but traces of the Atlantic deep water are not found in the South Georgia region but much farther to the east, since the easterly flow of the water is considerable. In the Bouvet region the admixture of water from lower latitudes leads to an increase of the salinity within the intermediate return current.

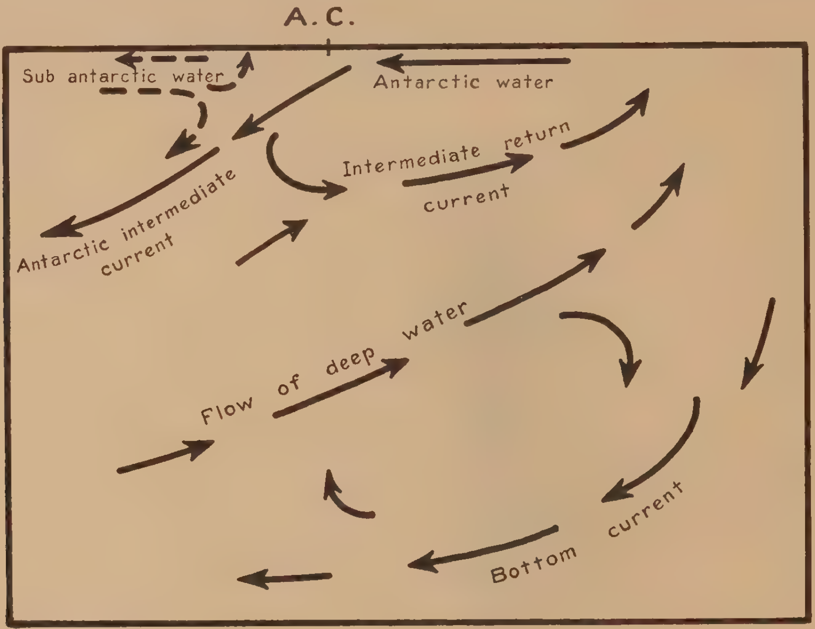

Fig. 23. Schematic representation of the north-south circulations within the Antarctic circumpolar current.

The conceptions of Merz and Wüst have been accepted by biologists who have studied the conditions in Antarctic waters. Ruud (1932), for instance, states that the oxygen of the relatively warm and saline layer is low, and says that "these water masses were last in contact with the atmosphere somewhere north of the Sargasso Sea, so a very long time has elapsed since they were aerated". He says, furthermore, "that the surface layer (of the Antarctic water) receives its nutrient substances from the richer intermediate layer of Atlantic origin". Our sections show, on the other hand, that the nutrient substances are carried back to the high southerly latitudes by the transversal circulation within the Antarctic Zone, and that the low oxygen values of the intermediate layer are local and must be due to processes within the transversal circulation.

An estimate of the velocity of the north-south circulation gives at present uncertain results, but a few numerical values may, nevertheless, be communicated. Let us suppose that the average wind velocity is about 10 m./sec. and that the tangential stress of the wind is

$$T = 3{\cdot}2 \times 10^{-6}\, W^2,$$

where W is measured in cm./sec. We then find $T = 3{\cdot}2$, and in latitude 55° S the total transport of water towards the north through a vertical surface which is 1 cm. wide will be $S = 2{\cdot}7 \times 10^4$ cm.^{3} In summer the thickness of the upper homogeneous layer which moves under the action of the wind appears to be 40–80 m. Introducing 60 m. as a probable mean value we find an average velocity towards the north of the pure drift current of about 4·5 cm./sec. If half of the return flow to the south takes place within an interval of depth of 300 m. the velocity of the southwards flow will be about 0·5 cm./sec., and the average speed of the transversal circulation within the upper layer about 2·5 cm./sec.

We have also other means of estimating the velocity within the intermediate return current. If the temperature distribution within this current is stationary we must have

$$\frac{A}{\rho}\frac{\partial^2 t}{\partial z^2} = \frac{\partial t}{\partial x} v_x,$$

where the x-axis is placed in north-south and where A is the coefficient of eddy conductivity and t the temperature. From the observations we find

$$\frac{\partial^2 t}{\partial z^2} \sim 2 \times 10^{-9}, \quad \frac{\partial t}{\partial x} \sim 2 \times 10^{-8}, \quad \rho \sim 1,$$

or

$$v_x \sim 0{\cdot}1\, A.$$

Our knowledge of the eddy conductivity in the sea is scanty, but at greater depths the values of the coefficient appear to range between 1 and 20 (Helland-Hansen, 1930). We, therefore, obtain

$$0{\cdot}1 < v_x < 2{\cdot}0.$$

This estimate only shows the order of magnitude of the component, and the agreement with our preceding value is, therefore, quite satisfactory.

It is also of interest to examine the time which one water particle would need for a complete transversal circulation in the upper layers. Within the Drake Passage and the Scotia Sea the north-south extension of the transversal circulation appears to be about 300 km., and thus the total distance which a particle would travel is about 600 km. Supposing the average speed to be 2·5 cm./sec. and neglecting the time which is needed during vertical displacements, we find that the particle returns to its most southern position after $2{\cdot}4 \times 10^7$ sec. or nearly 275 days. The time needed for vertical displacements can also be estimated. Suppose that the volume of water which is transported to the north through a vertical surface 1 cm. wide, $2{\cdot}7 \times 10^4$ cm.^{3}/sec., is replaced by water which is drawn towards the surface within a belt, which is 100 km. wide. The velocity of the vertical component will then be only 0·0027 cm./sec., and a water particle needs 80 days in order to cover a vertical distance of 200 m. The total time used for a complete circuit in the region to the east of Drake Passage is, therefore, at least one year.

The transversal circulation is no doubt more rapid within the Drake Passage and the Scotia Sea than in any other region because the Antarctic water is there pressed together. Comparisons of the sections in the Drake Passage with those in the Pacific and the Atlantic show this clearly. This feature is perhaps of considerable importance to several of the biological problems of the South Atlantic. It is possible that the surface water to the east of South Georgia left the surface in the Drake Passage or the Scotia Sea in the preceding year, while water masses which are drawn to the surface in the Pacific Antarctic Ocean have spent years at intermediate depths after they left the surface. This difference in the history of the water masses may in part explain the difference in the development of plant and animal life in the two regions.

Until now we have disregarded the circulation which, within wide areas, takes place to the south of the Antarctic current, along the Antarctic Continent. Near the Continent the wind direction is easterly, and in agreement with this direction we find currents towards the west in high southerly latitudes. Several whirls of stationary character appear to exist, and these are present partly because of the prevailing winds and partly because of the bathymetric features.

Within the westerly currents along the Continent we must also find a vertical circulation which is similar to the vertical circulation within the Antarctic easterly current. The surface layers are transported to the south by the pure drift current which is upheld by the prevailing easterly winds, and as compensation the water must flow north at some lower depth. We know that the bottom water flows towards the north, and within the Weddell Sea the water at a depth of about 500 m. also appears to have a component to the north. The latter current represents, however, not a direct return of surface water because it has a higher temperature than any other water mass in high latitudes. It must have been drawn south at an intermediate depth within some of the whirls.

In this connection it is of interest to draw attention to the following feature: The light water which is carried by the wind towards the shelf of the Antarctic Continent is effectively cooled on the shelf. The tendency of the wind is to accumulate light water along the coast and thus build up a stronger and stronger solenoid field, but this tendency is effectively counteracted by the cooling of the water. Here we thus have an example showing how factors which influence the density of the water prevent the development of a strong solenoid field under the action of the wind.

In the preceding part of this paper it has been attempted to give a picture of the vertical circulations within the Antarctic circumpolar current, starting out from general considerations as to the effect of the wind. The observations of the Discovery Expeditions indicate that circulations of the supposed character are present, but many questions still remain open and in conclusion some of these will be pointed out. The existence of the Antarctic Convergence and the character of the movement of the water near the convergence must be explained. In connection with the latter question one difficulty will be mentioned. Since the general wind direction is westerly on both sides of the convergence a transport to the north must take place on both sides. We have assumed that the transport is greater on the southern side and that, therefore, part of the water must sink near the convergence. It seems to follow that another part continues across the convergence, but the abrupt change in temperature when crossing the convergence is decidedly against such a view. The convergence seems to represent a narrow zone of mixing, but no continuous flow across takes place. A possible motion near the convergence is indicated in Fig. 23 by dashed lines. It is supposed that a return flow towards the south exists also on the northern side of the convergence, but this return flow takes place near the surface and at the convergence part of the water bends up towards the surface and is carried north, while another part bends down and joins with the Antarctic water and forms one constituent of the Antarctic intermediate current.

Another difficulty is met with in the southern part of the Antarctic current where returning water is supposed to reach the surface again. The observations show that the water of the intermediate return current approaches the surface in high southerly latitudes, but at no station is water of this type met with above 150–200 m. If our conception is correct, it must be assumed that the factors which influence the temperature and the salinity of the upper layers are so effective that the properties of the intermediate return water are changed when this approaches the surface. This assumption is not unreasonable, since the ascending motion is very slow.

The questions which have been mentioned here can perhaps be cleared up, partly by means of theoretical considerations, partly by means of new observations or by a closer study of the existing data. At present the above representation of the vertical circulation within the Antarctic circumpolar current must be regarded as hypothetical, but it is hoped that the consideration of vertical circulations which are maintained by the action of the prevailing wind may be helpful when studying the structure of other currents.

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A GENERAL ACCOUNT OF THE HYDROLOGY OF THE SOUTH ATLANTIC OCEAN

By

G. E. R. DEACON, B.Sc.

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A GENERAL ACCOUNT OF THE HYDROLOGY OF THE SOUTH ATLANTIC OCEAN

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(Plates VIII–X; text-figs. 1–24.)

INTRODUCTION

For some years past the Discovery Committee has been conducting a series of observations on the hydrology and plankton of the South Atlantic and Southern Oceans. During this period a large quantity of hydrological data has been accumulated, and as soon as the analyses of the results are completed, detailed papers on different aspects of the work will be published in this series of reports. In the meantime, and because such knowledge is of importance to those who are studying the plankton, the following general account of the hydrology of the area has been prepared.

THE SURFACE WATERS OF THE SOUTH ATLANTIC OCEAN

An examination of the distribution of temperature and salinity in the surface layers of the South Atlantic Ocean shows that there are four kinds of water at the surface. Each of these waters has a typical range of temperature and salinity, and typical conditions for the support of animal and plant life. The different bodies of water are closely dependent on the climatic conditions of the regions in which they lie, and they owe their existence partly to these conditions. The Antarctic climate in the south gives rise to a cold poorly saline surface layer of Antarctic surface water, and the tropical conditions near the Equator to a very warm surface layer of tropical water. Also, in addition to these two extremes, there are two intermediate types, sub-Antarctic and sub-tropical waters, which are affected less directly by Antarctic and tropical conditions. The geographical distribution of the four kinds of water affords a very convenient and significant method by which the surface of the South Atlantic Ocean can be divided into four zones, and a description of the hydrological conditions in each zone is almost all that is necessary to define the conditions over the whole ocean. The four zones have been called: Antarctic, sub-Antarctic, sub-Tropical, and Tropical.

In this report an account is given of all four types of water, and of the geographical limits in which they are found; but the paper is concerned principally with the hydrological conditions in the Antarctic and sub-Antarctic Zones.

ANTARCTIC SURFACE WATER

NATURE OF THE ANTARCTIC SURFACE LAYER

In the Antarctic Zone the surface layer is composed of cold poorly saline water, which lies in a shallow well-defined layer above warmer deep water. It has a depth of 100–

250 m., and is separated from the warm water below it by a discontinuity layer, within which the temperature and salinity increase rapidly with depth. Figs. 1 and 2 show the vertical distribution of temperature and salinity in a section through the surface 1000 m. of water along longitude 80° W, from 60 to 67° S. The position of the section is shown as section I in Fig. 11 (p. 191). The observations on which the sections are based were made in October, when the hydrological conditions had hardly changed from those of winter.

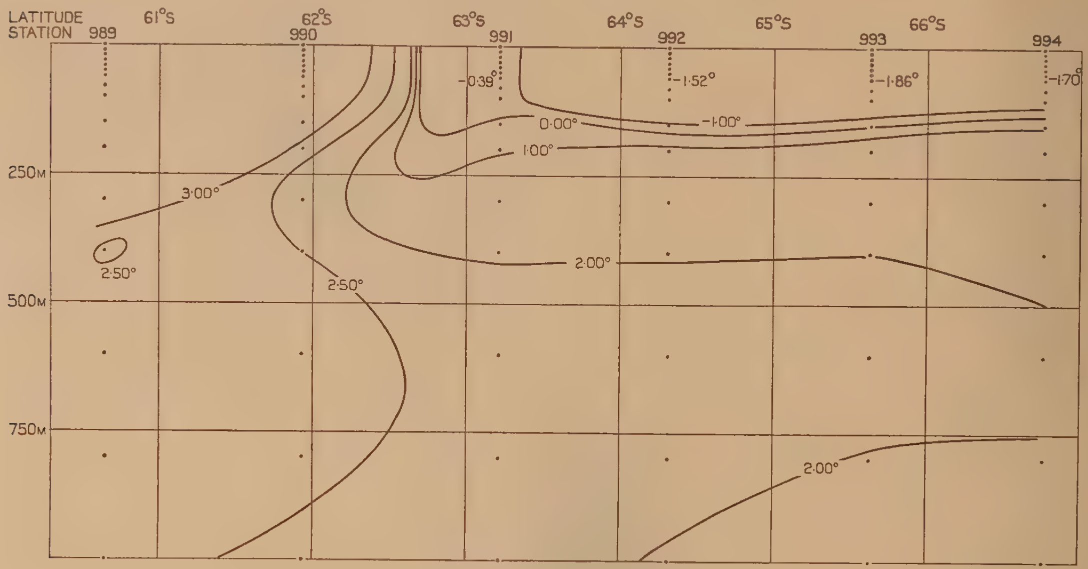

Fig. 1. Section I, distribution of temperature (° C.).

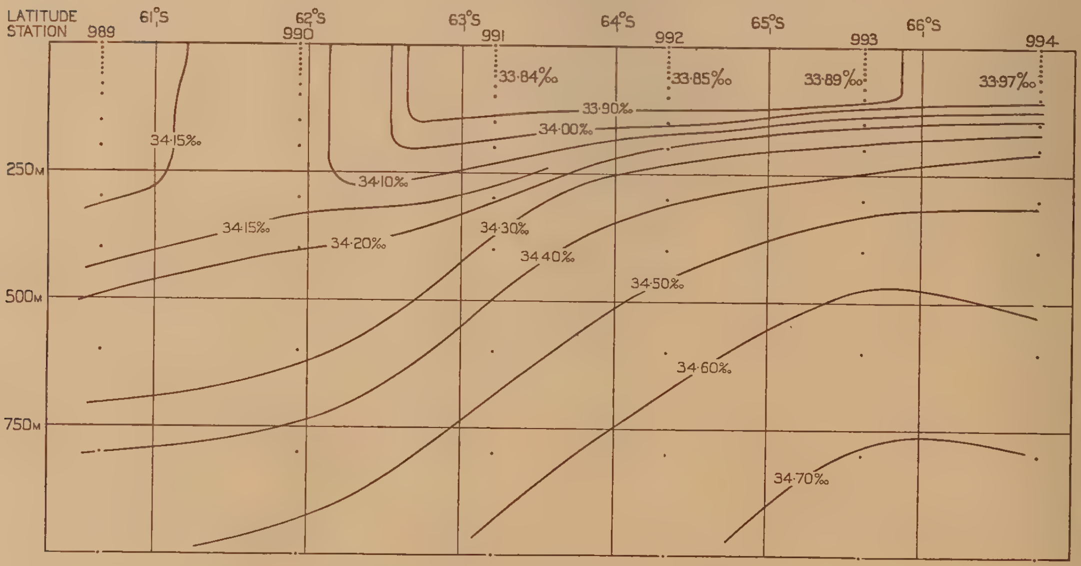

Fig. 2. Section I, distribution of salinity.

In Fig. 1 the Antarctic surface water is seen at the southern end of the section as a cold surface layer, in which the temperature is for the greater part less than − 1° C. The discontinuity layer is shown where the − 1°, 0°, and 1° C. isotherms crowd close together, and the depth of this layer below the surface increases gradually from about 100–150 m. in 67° S to 150–200 m. in 64° S. Below the discontinuity layer lies the warm deep water. At each of the four stations made in Antarctic surface water the temperature does not alter until at least 100 m. below the surface, and the temperature of this 100-m. stratum at each station is shown in the section. The water is not coldest in the extreme south, for there, as will be shown later, it is warmed slightly by upwelling deep water. Instead, the temperature decreases from − 1·70° C. at the edge of

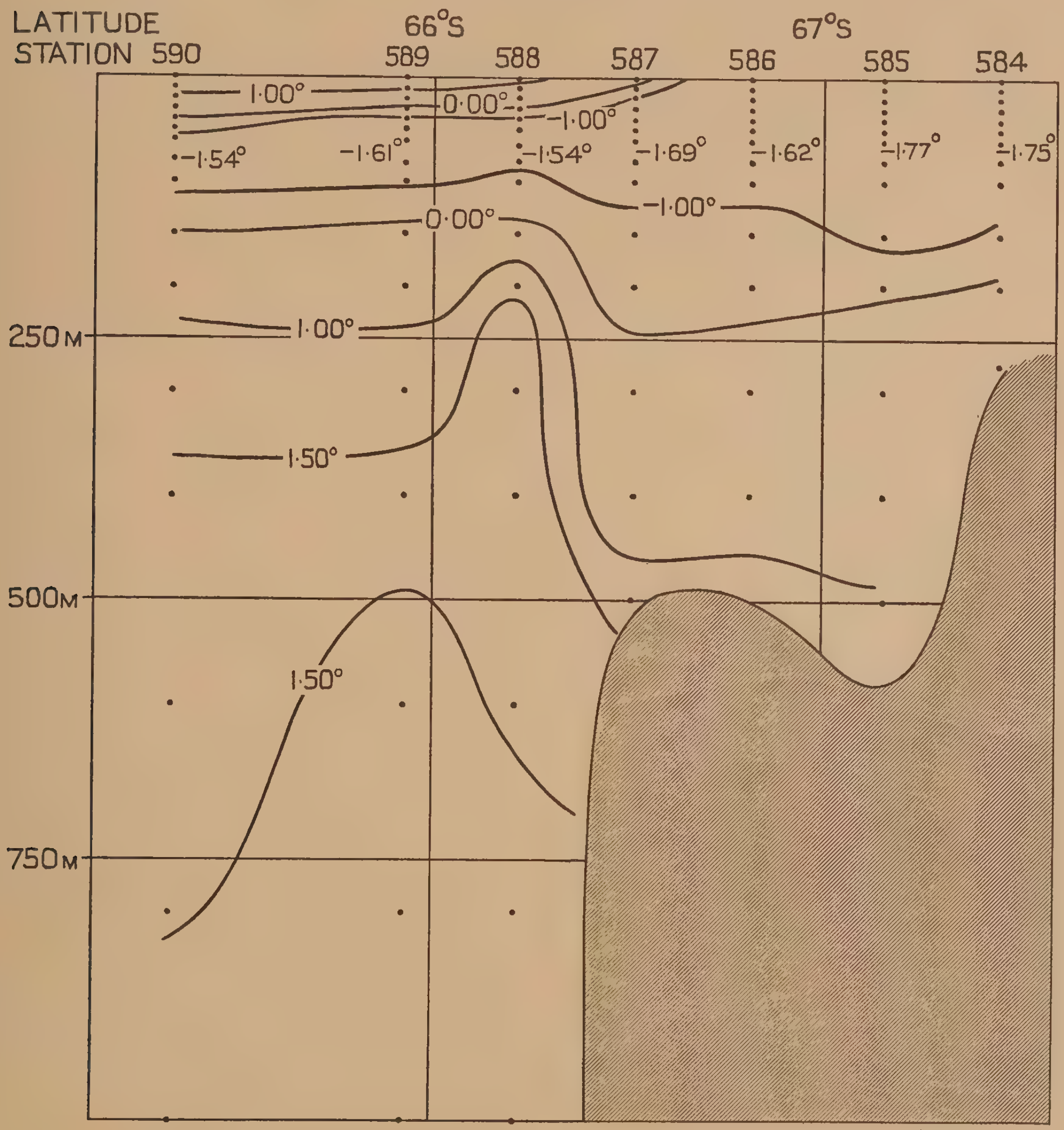

Fig. 3. Section II, distribution of temperature (° C.).

the pack-ice to − 1·86° C. at St. 993 and then increases gradually towards the north. Towards the northern limit of the Antarctic surface layer the increase in temperature is more rapid, until in 62° 37′ S the convergence of Antarctic with sub-Antarctic water is reached.

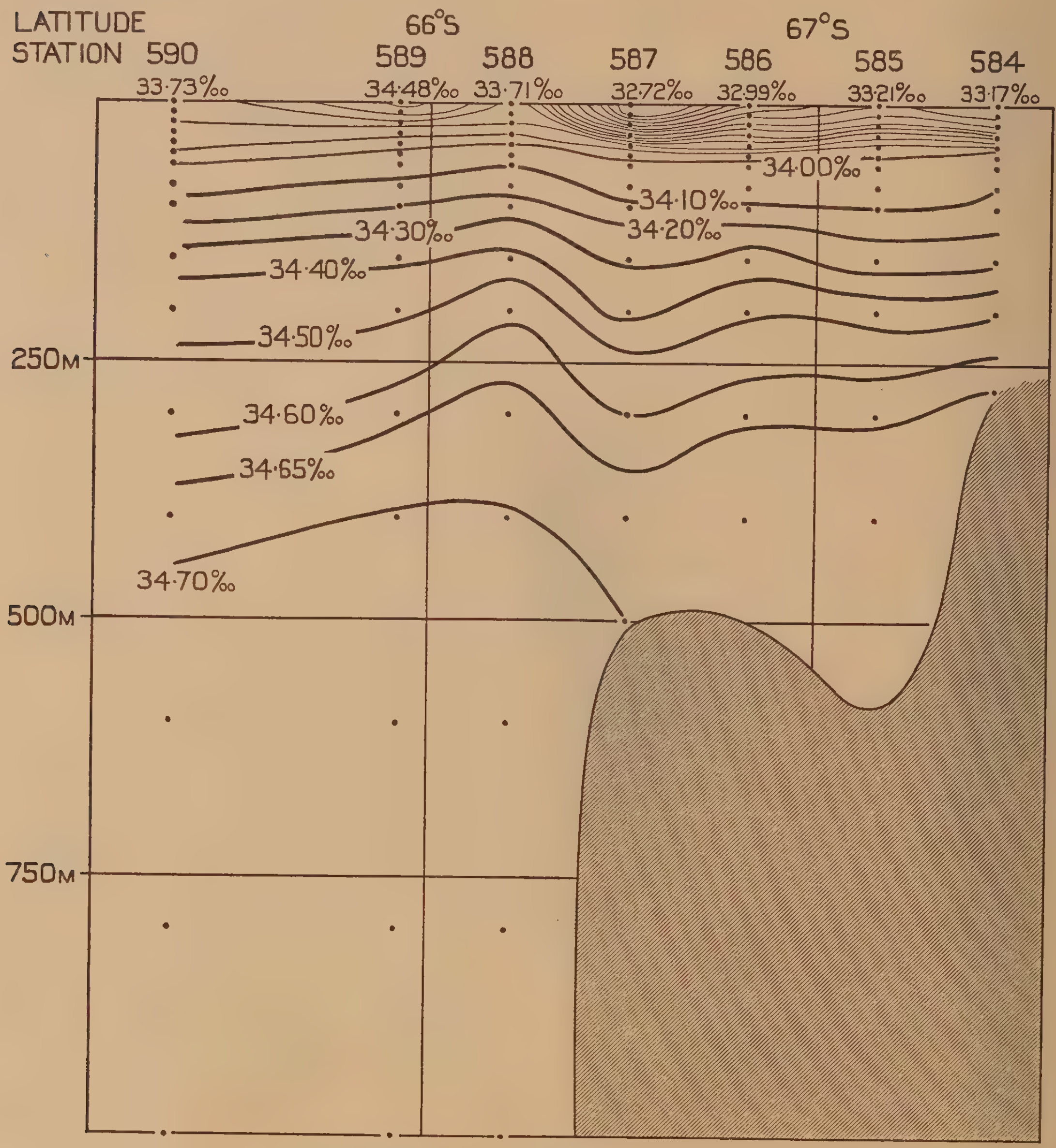

Fig. 4. Section II, distribution of salinity.

In Fig. 2 the Antarctic surface water is seen as a poorly saline surface layer with a salinity less than 34 °/$_{00}$. Its salinity does not change with depth in the first 100 m. below the surface. The salinity is greatest at the edge of the pack-ice and decreases slowly towards the north. Figs. 1 and 2 together show that the Antarctic surface layer in winter is composed of almost homogeneous, cold, poorly saline water. There is practically no change in it with depth above the discontinuity level. The changes from south to north are also very small, except in the neighbourhood of the convergence with sub-Antarctic water.

In summer the conditions are quite different. Figs. 3 and 4 show the distribution of temperature and salinity in a vertical section through the southern half of the Antarctic surface layer in summer. The section was made along a line north-west of Adelaide Island and its position is shown as section II in Fig. 11 (p. 191). Although section II was made in shallower water than section I the positions are not very far apart, and a comparison of Figs. 3 and 4 with Figs. 1 and 2 shows how the layer changes from winter to summer. Fig. 3 shows that in summer the surface of the layer is warmed, and the temperature no longer remains constant with depth down to 100 m. Instead, the temperature decreases with depth until a level is reached in which it is not much different from the value it would have in winter. In summer there are two strata in the layer, a surface stratum which has been warmed by the greater absorption of heat from radiation, and by conduction, and a cold stratum where the water has been warmed hardly at all. The minimum temperature in the cold stratum at each station is shown in the section. In winter the salinity of the surface layer will be greater in section II than it is in section I, because section II is closer inshore and affected to a greater extent by

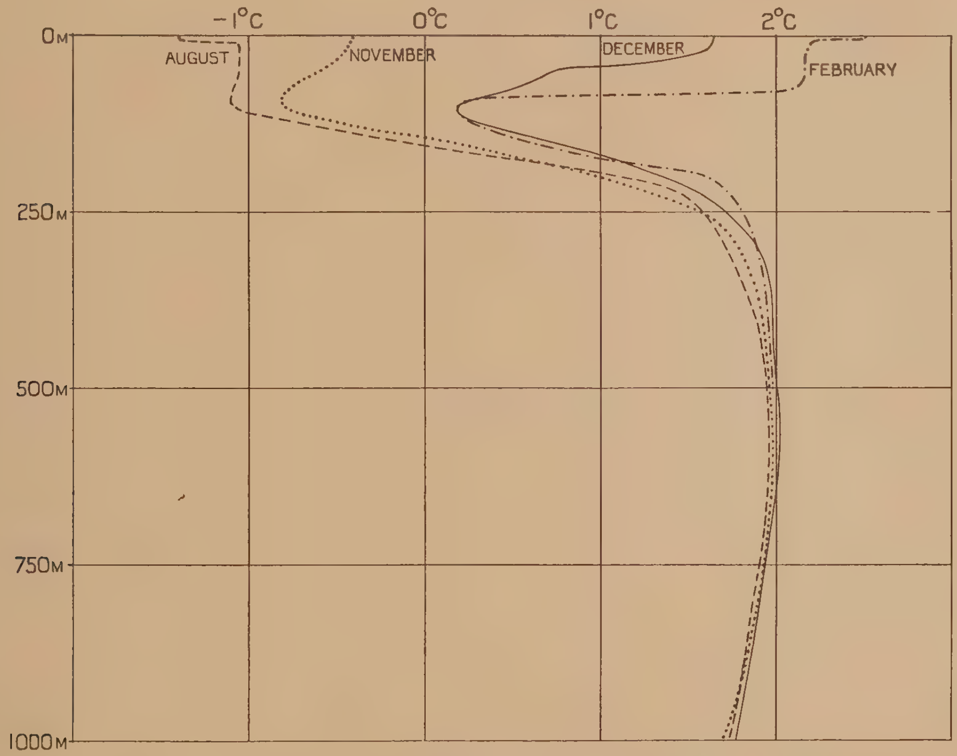

Fig. 5. The change in temperature with depth in the Antarctic Zone.

upwelling deep water. In summer, however, as shown in Fig. 4, the surface salinity is much less than it is in section I. At the surface the minimum salinity is found at St. 587, which is directly in the path of the surface current from pack-ice which was lying to the south-west. The surface stratum has been diluted with fresh water from melting ice, and by drainage from Antarctic land. The salinity of the water in the cold stratum is still greater than it is at the same depth in section I: it has not been lessened by dilution to anything like the same extent.

The changes which take place in the layer with the approach of summer are also shown by diagrams illustrating the way in which the temperature, salinity, and density of the water change with depth in different seasons of the year. The four curves in Fig. 5 show the change of temperature with depth at a point 50 miles north of Prince Olaf Harbour, South Georgia, in August, November, December, and January. They show the changes which take place in the Antarctic surface layer not very far from its northern boundary. In August the layer is cold and homogeneous, a condition which is typical of winter. In November the surface has been warmed, and so to a much lesser extent has the cold stratum. Warming goes on throughout the summer, until in February the surface is 3·9° C. warmer than it is in winter and there has been a corresponding increase of 1·3° C. in the cold stratum.

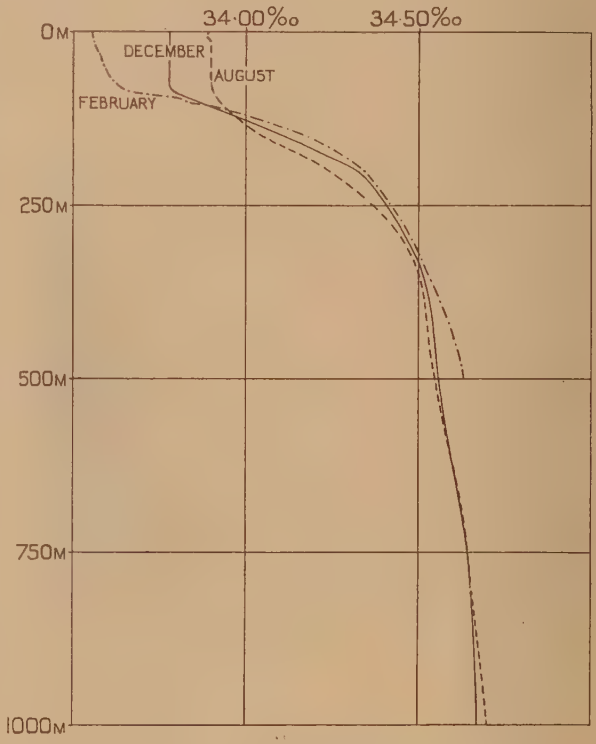

Fig. 6. The change in salinity with depth in the Antarctic Zone.

Fig. 6 shows the changes in salinity with depth at the same stations in August, December, and February. In August the salinity does not alter with depth down to 100 m., and the layer has it greatest salinity. In December the salinity is less, but it is still uniform down to 80 m. In February the layer has its least salinity and there is a greater increase in salinity with depth. The changes in density which take place in the layer are important because of their effect on vertical mixing both in the layer itself and between the layer and the warm deep layer below it. Fig. 7 shows the vertical distribution of σ_t at the same stations[1].

In August the surface layer has its greatest density. In December it is warmer, less saline and lighter, and in February, when the effects of warming and dilution are greatest, its density is least. Since the density of the layer is greatest in winter and least in summer, the discontinuity between it and the warm deep water (whose density remains fairly constant) is in winter least effective as a hindrance to vertical mixing between the two layers, and in summer most effective.

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[1] $\sigma_t = (S_t - 1)\,1000$, where S_t is the specific gravity of the sea water at t° C. referred to distilled water at 4° C.

The conclusions drawn from the changes in temperature and salinity at these stations near the northern boundary of Antarctic surface water are in general the same as those drawn from sections I and II farther south. The surface of the layer is warmed and diluted with fresh water in summer, and there is still a cold stratum in which the conditions are least changed from those of winter. The results show, however, that there is an increase in vertical mixing from south to north in the layer. Far south there are sudden changes in salinity with depth near the surface. Farther north these changes are more gradual, and although the surface stratum no longer has such a low salinity there has been a greater reduction in the salinity of the cold stratum.

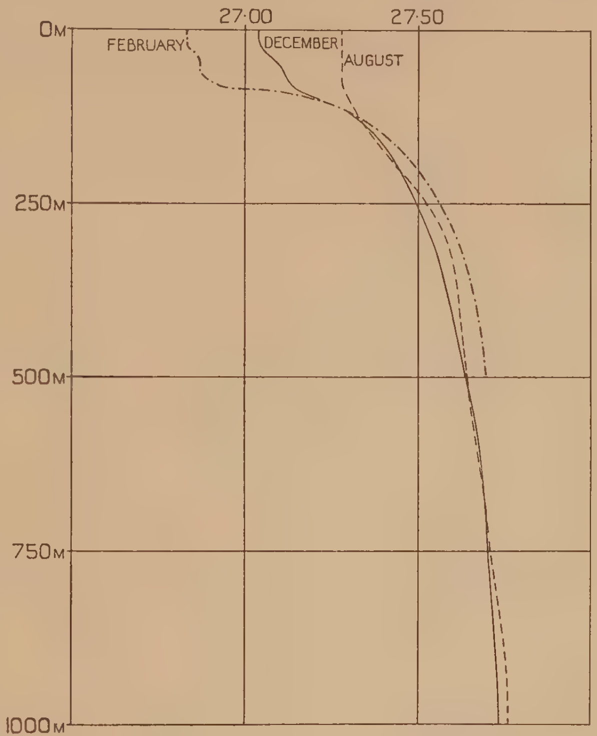


Fig. 7. The change in density (σ_t) with depth in the Antarctic Zone.

ORIGIN OF THE ANTARCTIC SURFACE WATER

The Antarctic surface layer is bounded in the south by the Antarctic Continent, and in the north by sub-Antarctic water along a convergence which has recently been shown to be continuous throughout the Southern Ocean. North of 66° S the direction of movement of the water in the surface of the layer is in general towards the north-east; south of 66° S it moves towards the west or south-west. The movement north of 66° S can be considered as having two components, one to the east and the other to the north. The easterly component will maintain a continuous current towards the east across the Southern Ocean but the northerly component will move water northwards towards sub-Antarctic water.

It will be shown later that along the Antarctic convergence, where the two waters meet, Antarctic surface water sinks below sub-Antarctic water, and after a good deal of mixing with it continues to flow northwards as a deep current. This water is lost from the Antarctic surface layer, and must be replaced.

It has been found that the surface currents in the Antarctic Zone are much more rapid in summer than in winter. The principal evidence in support of this conclusion is obtained from topographical maps, which show the height of the surface, calculated from dynamic data, above some deeper isobaric surface which can be assumed to be level. These maps indicate that the Antarctic surface currents in the Falkland Sector are about twice as fast in summer as in winter. Further evidence, which is, however, not conclusive, can be obtained from the movements of pack-ice. In the year 1930, for example, there was no pack-ice north of South Georgia in August, September, or October, and its appearance in November can be attributed to the speeding up of the surface currents with the approach of summer. It would also be expected that the Antarctic convergence would move northwards as the speed of the surface currents increases; but the evidence we possess does not support this conclusion. Few observations have, however, been made in winter and those available are not sufficient to disprove a seasonal movement of the convergence.

Although it is only in the Falkland Sector that there are sufficient data to examine the seasonal changes in the speed of the surface currents and in the extent of the layer it can safely be assumed that there is a greater production of Antarctic surface water in summer than in winter. This increased production can be explained by the great additions of fresh water which the layer receives in summer from melting ice and as drainage from the land. In winter these sources are for the greater part stopped, and the activity in the layer diminishes. The origin of Antarctic surface water does not lie entirely in the addition of fresh water to the layer in summer, or to a lesser extent in winter. There must be further additions to the layer from a different source to maintain its salinity. It will be shown later that besides the transport of Antarctic water towards the north in the surface there is also a flow of Antarctic water northwards in the bottom layer. To compensate for the loss of water towards the north by these two currents, which are known to exist all round the Antarctic Continent, there must be a return current towards the south in the intermediate depths. Also, between the cold Antarctic surface layer and the cold Antarctic bottom layer there is a maximum temperature in the warm deep layer. This maximum temperature, in water which lies between two bodies of colder water, can be maintained only by a movement of water southwards in the warm deep layer. A second source of Antarctic surface water is therefore to be expected in the warm deep water.

A certain amount of mixing must always take place between the two layers across the discontinuity layer which separates them, especially in winter. It is principally to be looked for in places where the density difference between the two layers is least, and in places where for hydrodynamical reasons, based on the direction of winds, currents, or the shape of land masses, the warm deep water is made to rise towards the surface. Warm deep water has never itself been found at the surface, although it has been found with its maximum temperature at a depth of only 100 m.: it is always covered with Antarctic surface water. In section I the salinity of the water at the station made at the edge of the pack-ice was greater than at those farther north; its temperature was also higher, and as will be shown in Fig. 18 (p. 204) its oxygen content was less. Each of these facts is explained by a greater mixture of the surface water with the warmer, more saline, and poorly oxygenated deep water. In section II there is shown a great upwelling of deep water at the edge of the continental shelf. The effect of the upwelling on the Antarctic surface layer is shown in the temperature and salinity sections, Figs. 3, 4, and also very plainly in Fig. 19 (p. 204), which shows the percentage of oxygen saturation of the water in section II.

Fig. 17 (p. 203) shows the percentage of oxygen saturation of a surface stratum of water 100 m. thick, in the Falkland Sector. It is a fairly accurate guide to the places where deep water is upwelling. There are objections to its use, but it has been found that where low percentages in the diagram show that poorly oxygenated deep water is upwelling, the upwelling is confirmed by the temperature and salinity data. From the figure it will be seen that the surface layer in the Falkland Sector receives most water from the warm deep layer along the west coast of Graham Land and the South Shetland Islands, and along that part of the ridge known as the Scotia Arc (Herdman, 1932, p. 214), which joins Joinville Island to the South Orkney Islands, and the South Sandwich Islands.

There is also considerable upwelling in other places outside the scope of the diagram, particularly in the centre of the cyclonic current system in the Weddell Sea. In winter the effect of addition of water from the warm deep layer to the Antarctic surface layer is partly the cause of the increasing salinity of the surface layer. In summer its effect is exceeded by that of additions of fresh water, and the salinity of the surface layer decreases. The relative importance of the two sources and their effect on the nutritive conditions in the surface layer has yet to be worked out.

The heavy precipitation in the Antarctic Zone is a third source of Antarctic surface water. G. Schott (1926) shows that the annual precipitation in the West Atlantic Ocean between 50 and 60° S is greater than 1000 mm. per annum, and this amount is about 700 mm. per annum greater than the amount of evaporation. A fourth influence, which increases the salinity of the layer in winter, is the deposition of salt when sea ice is formed. Neither of these last two factors is negligible and their importance is being investigated.

The sources of Antarctic surface water can be summarized as follows:

(1) Fresh water from melting ice and snow.
(2) Warm water of high salinity from the warm deep layer.
(3) Fresh water from the excess of the precipitation over evaporation, partly allowed for in (1).
(4) Salt which is deposited when sea ice is formed.

There are also several influences directly due to the Antarctic climate which are necessary to maintain the layer. These are (i) conduction and radiation of heat into the layer in summer, and out of it in winter, and (ii) strong vertical mixing due to turbulent movement under the influence of strong winds. It is important to remember that north of 66° S the water in the layer is part of a continuous movement towards the east, and that to the south of this latitude its movement has a westerly component.

The additions to the layer are made therefore to a water mass which is large enough, and lasting enough, to show some resilience to changes. If Antarctic water flowed only towards the north much greater seasonal changes would be expected.

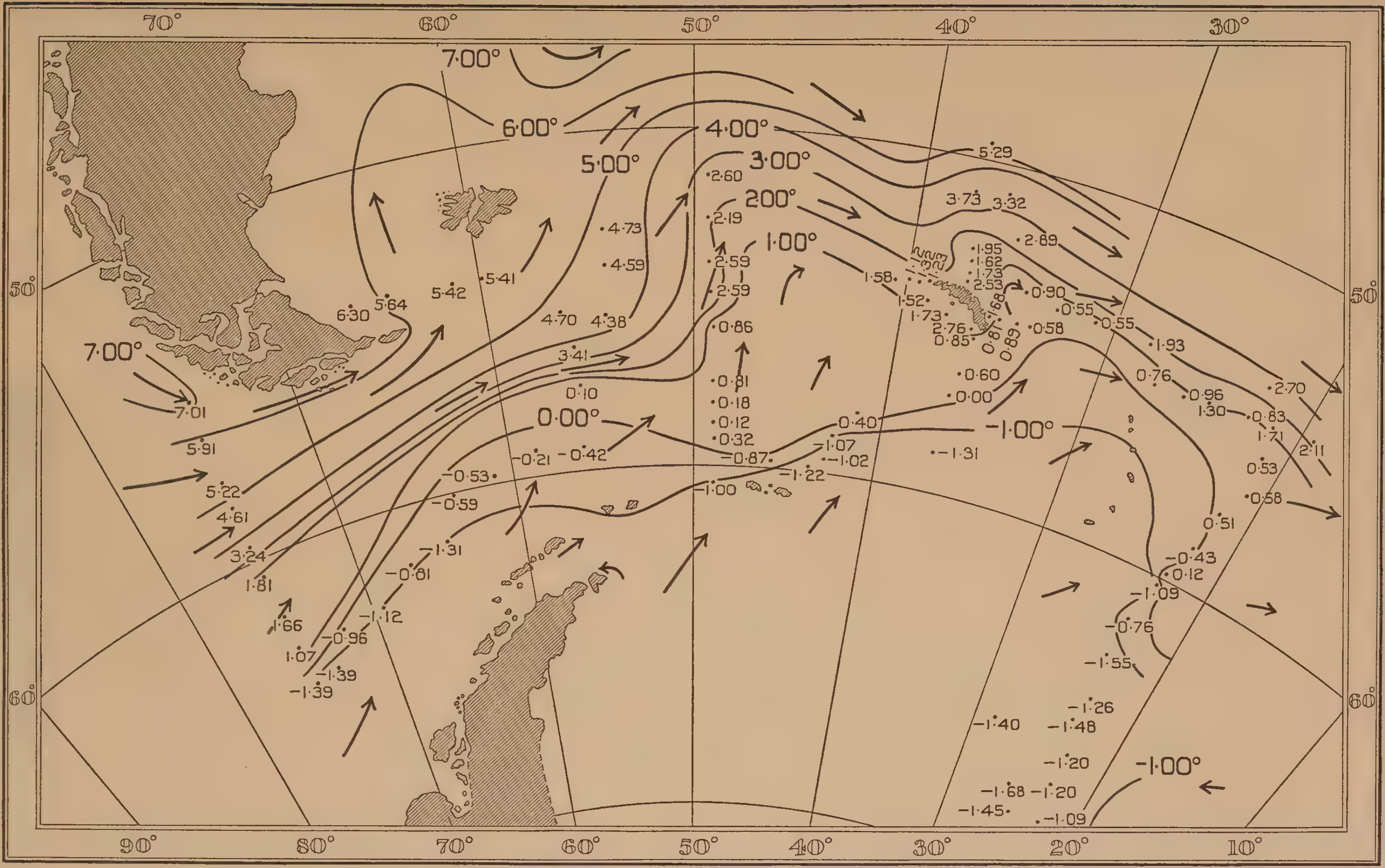
MOVEMENTS OF THE ANTARCTIC SURFACE WATER IN THE FALKLAND SECTOR

Present knowledge of the surface currents in the Falkland Sector is based principally on evidence obtained from charts showing the distribution of temperature and salinity, and from charts showing the topography of the sea surface relative to a deep isobaric surface, which because of the lesser movement at great depths has been assumed to be horizontal. The general conclusions from these charts are shown as current arrows in Fig. 8. The length of the arrows is intended to give an approximate idea of the relative speed of the surface currents, but more precise information and topographical charts will be given in a later report.

There are three principal factors which cause movement in the Antarctic surface layer, and they can be summarized as follows:

(1) A thermohaline influence, which produces a vertical circulation in the ocean as a result of density differences maintained in different latitudes largely by different climatic conditions.
(2) The effect of the prevailing wind systems and pressure differences.
(3) An effect due to the excess of precipitation over evaporation, and to the liberation of fresh water when ice and snow melt in summer.

The low air temperature and the small heating effect of the sun in the Antarctic regions give rise to heavy water at the surface: this water, although it has a low salinity, is still heavier than the more saline but warmer water in the tropical and sub-tropical regions. The presence of this heavy surface water in the south is shown by the slope of the isobaric surfaces in the sea downwards from south to north. The slopes of the 0, 300, 600, and 1000 decibar surfaces relative to the 3000 decibar surface are shown in Fig. 9 (p. 184). Since the 3000 decibar surface can be regarded as almost horizontal they may be taken to represent the actual slopes. The vertical scale is in "dynamic centimetres," each of which equals 1·02 cm., and the figure shows the difference between the depths at which the isobaric surfaces were found and the depths of the horizontal positions they would occupy in a uniform and motionless sea of 0° C. and 35 °/₀₀ salinity. Because the water at the southern end of the section is heavier than that in the north the same pressure is reached at lesser depths. The presence of heavier surface water in the south is partly due to the presence of a movement towards the east, south of 40° S, which is maintained by an external factor, the wind. In this movement the layers of equal density will attain a more or less constant slope downwards to the north; but there is ample evidence to show that the slope is also the result of a continuous meridional circulation.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−0·76
−1·55
−1·26
−1·48
−1·40
−1·20
−1·68
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−1·45
−1·09

Fig. 8. The surface isotherms and currents in the Falkland Sector (° C.).

It has been shown by Jeffreys (1925) that if a difference in temperature is maintained over any level surface within, or in contact with a fluid, the fluid will move, and continue to move, until such difference of temperature ceases to exist. From the application of this principle to the South Atlantic Ocean it is evident that there must be a movement of Antarctic water to the north, and of warmer water to the south, in a continuous circulation.

The circulation is not so simple as that described by Lenz (1847), who imagined a symmetrical circulation in both hemispheres with water sinking near the poles and rising towards the surface near the Equator. It is, on the contrary, the result of heavy Antarctic surface and bottom waters sinking to different levels in the south, and of water of subtropical origin sinking into the intermediate level from the North Atlantic. The circulation will be discussed in detail in the section of the report dealing with the deep waters.

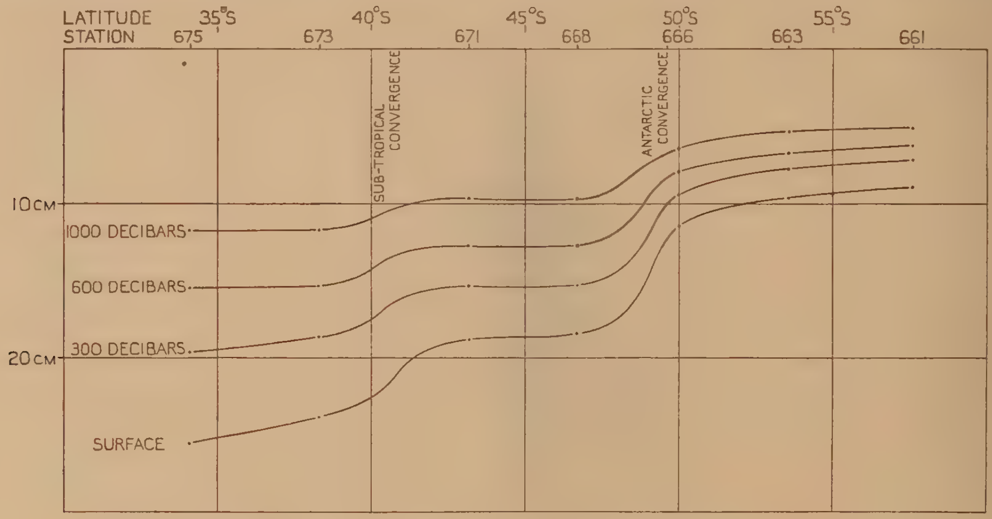

Fig. 9. The slope of the 0, 300, 600, and 1000 decibar isobaric surfaces in 30° W.

For the present it can be seen from Plate VIII that the shape of the isotherms and isohalines in vertical sections which show the distribution of temperature and salinity in the South Atlantic Ocean indicates that both Antarctic surface water and sub-Antarctic water sink towards the north. This is also seen in Plates IX and X which give the vertical distribution of phosphate, nitrate, and oxygen content, and it is also indicated by the presence of water farther north in the deep levels which can only have had its origin south of the convergences. Such a movement of Antarctic surface water is explained by Jeffreys' work. Although unable to sink vertically because of the still heavier water which is found below it, it can sink towards the north and still remain above the heavier water. The south to north movements of Antarctic surface water can be explained therefore by the effect of the thermohaline influence.

The greatest movement in the layer, except in some parts of the Falkland Sector, is, however, probably to the east, north of 66° S, and to the west, south of 66° S, and these movements can only be explained as due to the influence of the prevailing winds.

North of 66° S the wind moves water northwards and assists the thermohaline influence. It is considered by some to be the sole cause of the south to north movement and also of the circulation in the ocean as a whole. Defant (1929, p. 133) says: "The thermohaline circulation is therefore quite a surface phenomenon; the lower layers in the ocean have no part in it", and on p. 134, "It is not to be doubted that in contrast with the thermohaline influences just mentioned, ocean currents produced by winds are more important, and give rise to the final structure of current systems in the sea". Defant also says on p. 136: "While acknowledging the winds to be the principal factor giving rise to a horizontal circulation, we must not overlook the importance of density differences as the origin of vertical circulation". There seems to be some contradiction between the three quotations, unless a circulation caused by density differences is distinct from a thermohaline circulation.

Our observations show that all the movement in the Antarctic surface layer cannot be explained entirely as the result of wind currents although the zonal movements are probably due almost entirely to wind forces. The south to north movements, particularly below the surface stratum, are part of a continuous circulation, which is the result of density differences. In the opinion of the author the density differences are largely thermohaline differences which are the result of the different climates in different parts of the ocean. The distribution of density may however be modified by the effects of wind and of neighbouring land masses, which give rise to movements of water from one climatic region to another. In the deep layers the density distribution is influenced by the topography of the sea bottom: a movement of heavy deep water may be forced to follow a particular channel, or it may be stopped by a ridge.

Before discussing the effect of wind on the movement of Antarctic surface water, it is necessary to describe the general conclusions which Ekman (1928) has reached on the effect of winds on the sea. Ekman distinguishes four types of current:

(1) A PURE DRIFT CURRENT caused by the effect of the resultant tangential force of the wind on the surface of the sea. The velocity of the water at the surface is deduced on the assumption that the sea is homogeneous, and that the coefficient of friction is constant, to be directed at 45° *cum sole*[1] from the direction of the wind. The direction of the surface current turns uniformly *cum sole* with depth, and at the same time its velocity decreases according to a logarithmic spiral until it is only one twenty-third of its surface value when the direction of movement has turned through two right angles. The depth at which this takes place has been called by Ekman "the depth of frictional influence", since, if small velocities less than 5 per cent of the original one are neglected, it shows the greatest depth to which horizontal motion can be transferred by friction. The depth of frictional influence is written D, and according to Ekman $D = \frac{7 \cdot 6 w}{\sqrt{\sin \phi}}$, where w is the speed of the wind in m./sec., and ϕ is the latitude. The formula, as pointed out by Ekman, can only be regarded as approximate; it gives a depth of 80 m. for a wind of

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[1] *Cum sole* is the direction of the sun's apparent azimuthal motion—anticlockwise in the southern hemisphere. *Contra solem* is the opposite direction—clockwise in the southern hemisphere.

about 20 knots in 60° S. Brennecke (1921) found by measurement a depth of 50 m. in the Weddell Sea. The total transport of water in a pure drift current is directed at 90° *cum sole* from the direction of the wind; and if the wind is from the west in the southern hemisphere, the total transport is towards the north. If the depth of the sea is less than 1·25 *D*, the angle between the surface current and the wind decreases; and when the depth is 0·1 *D*, the surface current is in approximately the same direction as the wind.

(2) A SLOPE CURRENT is the direct result of the transport of surface water in the pure drift current which will cause the level of the sea to rise at one place and fall at another. To prevent this slope of the sea surface a deep current flows in a direction at right angles *cum sole* from the direction of the slope, i.e. in the direction of the wind. The velocity of this slope current is constant with depth, if the sea is homogeneous and friction constant, until a depth is reached where the frictional influence of the bottom is felt.

(3) A BOTTOM CURRENT, which is the slope current modified by the effect of friction with the sea-bottom. Below a height from the bottom which is analogous to the depth of frictional influence at the surface—it may be called the depth of lower frictional influence or the effective height of bottom friction—the slope current is slowed down by friction and is turned *contra solem* to flow in the direction of the surface slope. When stationary conditions have been reached, the bottom flow in the direction of the slope is all that compensates for the surface flow up the slope.

4. CONVECTION CURRENTS. Ekman also recognizes the presence of currents, if the water is not homogeneous, which are due to instability in the distribution in density. Their speeds and directions depend on the angles and directions of slope of the surfaces of equal density.

In the Antarctic surface layer the effect of the prevailing west wind north of 66° S is to set up pure drift currents with surface velocities towards the north-east, and with a total transport of water towards the north. As far as can be shown at present the depth of frictional influence is about 60–80 m. The surface stratum of Antarctic water is very often uniform to this depth, especially after a storm, and it will be shown in the section on salinity and temperature of Antarctic surface water, that the changes with depth below 80 m. are always much greater than those above it. In sub-Antarctic water, also, there are changes at about 80 m. which are caused by a component of movement southwards. It therefore seems probable that the effect of pure drift currents is confined to the surface 80 m. of water, and the movement of the colder water at the bottom of the layer will be part of the deep current. According to Ekman it will move as a slope current or a convection current or a combination of the two. The total effect of the prevailing westerly wind on the Antarctic surface layer will be to produce in the cold stratum a current towards the east, and in the surface stratum a current which has at each level the velocity of the pure drift current at that level superimposed on the easterly movement of the cold stratum.

South of 66° S the prevailing wind is from the east and the direction of movement will be towards the west at the bottom of the layer, and at the surface, south of west.

These movements are known to exist and the wind is probably almost entirely responsible for them. At the northern end of Graham Land a little water flows westwards against the wind, into the Bransfield Strait. This may be due to the effect of the earth's rotation on the Weddell Sea current flowing towards the north-east out of the Weddell Sea, or to the presence of a counter-current between the Weddell Sea current and the Bellingshausen Sea current which also flows towards the north-east outside the Weddell Sea water. The effect is a very minor one compared with the easterly movement in the same region.

There must, however, also be a northerly movement in the cold stratum of the Antarctic surface layer, almost as strong as the northerly movement in the surface stratum. This is shown by the amount of water sinking at the convergence which is colder than the water in the surface stratum. Also, if the water found in the cold stratum near the northern boundary of the zone were not continually renewed from the south, the minimum temperature in the cold stratum would disappear, as a result of mixing with the warmer water above and below it. Such a northerly movement can be explained as part of the thermohaline circulation, and it is to this circulation, in all probability, that north and south movements are mainly due.

Because Antarctic surface water sinks below the surface at the Antarctic convergence there must be a greater movement towards the north in the Antarctic surface layer than there is in the surface layer in the sub-Antarctic Zone. This is not the result of a difference in the strength of the pure drift currents in the two waters, since, as is shown by Table XII (p. 236), the wind is strongest north of the convergence. The convergence is, moreover, sharp and the Antarctic water sinks suddenly, and there is no corresponding sudden change in wind velocity which could produce a sharp convergence. These are facts which afford additional reasons for believing that the northerly movement is not purely a wind current but a convection current caused by density differences.

The greater speed with which the surface water moves in summer cannot be explained as the result of stronger winds in summer than in winter, since the winds are approximately of the same strength in both seasons (Schott, 1926, p. 224, and Ardley, p. 235, *infra*). The increased speed can be explained by the thermohaline circulation, in so far that there is a greater production in summer of surface water which is heavier than that farther north; but it is perhaps best explained as the result of a third factor —the liberation of fresh water in summer. According to Schott the precipitation between 50 and 60° S in the West Atlantic exceeds 1000 mm. per annum, and according to Cherubim (1931, pp. 325–35) the amount of evaporation is just less than 300 mm. per annum.

Ekman (1926, p. 261) has studied theoretically the production of ocean currents in the sea which would be caused directly by the difference in precipitation in different regions in the ocean. He has shown that the greatest velocity of such currents is 1–2 cm./sec., and that they will probably be only a fraction of this. In the Southern Ocean, however, the snow which falls far south does not melt until summer approaches, and then it is released quickly. There are the additional effects of drainage from the land, where the snow also melts in summer, and the melting of sea ice which has been forming during winter and of land ice brought down to the sea by glaciers.

It is this fresh water, released in summer and mixed with Antarctic surface water, which streams away from the ice and eventually flows north-east, speeding up the surface movements. The effect of fresh water on the surface layer will be discussed in greater detail in the section on the temperature and salinity of Antarctic surface water. The direction of the current formed by the addition of fresh water to the Antarctic surface layer will be away from the ice, so that accumulation of water near the ice is prevented. Its direction will be modified by the effect of winds and the effect of the earth's rotation. It will also be influenced by the shape of the land masses and the configuration of the sea bottom.

There are two principal currents of Antarctic surface water in the Falkland Sector. One of these flows towards the north-east out of the Bellingshausen Sea. It has been shown that the westerly winds extend farther south in the Pacific than they do in either the Atlantic or Indian Oceans, and south of 66° S there is still a surface current towards the east. This current is turned towards the north by the west coast of Graham Land and then flows towards the north-east through the Drake Passage. The distribution of temperature in vertical sections across the Drake Passage shows that the current is strongest at the edge of the continental shelf, for it is there, off the South Shetland Islands, that the lowest temperatures are found.

In the western half of the Scotia Sea the direction of the current is largely influenced by the shape of the bottom. Ekman (1928) has shown that in high latitudes the deep currents in the sea tend to follow the lines of equal depth, and in the Southern Ocean this is not only true of the deep currents but also to a certain extent of the surface currents, to which the effect is transferred by friction or by the effect which a change in direction of the deep current has on the density distribution. North of the Scotia Sea there is a well-defined ridge, the Scotia Arc, extending from Cape Horn and the Burdwood Bank to South Georgia. There is a gap in the ridge between 48 and 49° W[1], where the water is deeper than 3000 m., but on the ridge between Cape Horn and 50° W there is nowhere a depth of water much greater than 1000 m. West of 50° W there is a trough of deeper water north of the ridge. The Bellingshausen Sea current is prevented from flowing northwards by the ridge: it follows the easterly direction of the ridge until the gap is reached. At the gap it turns northwards, and then westwards into the deep trough north of the ridge, as well as eastwards across the Atlantic Ocean. The changes in direction of the surface current are reflected in the shape of the convergence in the neighbourhood of 50° W, which is shown in Fig. 11 (p. 191).

East of 50° W the Bellingshausen Sea current north of the Scotia arc probably has a small component southwards, towards the western end of South Georgia, since the isotherms in the surface recede towards the south. Such a component might be the result of the southward flow of water in the Brazil current, the effect of which on the temperature distribution can be seen in Fig. 8 to the north-east of the Falkland Islands.

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[1] Herdman, 1932, pl. xlv.

If it is caused by the Brazil current the strength of the southerly component will decrease towards the south and Antarctic surface water will still sink below the surface at the Antarctic convergence.

As it leaves the Drake Passage the Bellingshausen Sea current is joined on its right-hand side by the Weddell Sea current. This current has its origin in water which has drifted south and west across the Atlantic Ocean south of 66° S under the influence of the easterly winds. This drift towards the west into the Weddell Sea, shown far south in Fig. 8, is turned northwards at the east coast of Graham Land, and finally flows out of the north of the sea past the South Orkney Islands. Part of it flows northwards towards the Shag Rocks, but most of it turns more eastwards under the influence of the westerly winds. A little turns westwards round the northern end of Graham Land into the Bransfield Strait, as has been mentioned earlier. The principal part of the current flowing east and north-east spreads out across the eastern half of the Scotia Sea. East of South Georgia it follows the lines of equal depth, and after crossing the ridge joining South Georgia to the South Sandwich Islands, part turns towards the west along the edge of the continental shelf east of South Georgia. It meets the Bellingshausen Sea water, which flows towards the western end of the island, and is turned back to the east. Then, with the rest of the current, it flows eastwards across the Atlantic. Even as far east as the longitude of the Cape of Good Hope Weddell Sea water can be distinguished on the surface as a cold current by a minimum temperature between 55 and 56° S. North of the minimum temperature is warmer water, which is the remains of the Bellingshausen Sea water, and south of it warmer water which is falling away into the drift towards the south-west.

Between the drift into the Weddell Sea and the Weddell Sea current flowing out of it, there is a cyclonic water movement with a long zonal axis. The axis lies between about 63 and 65° S, probably nearer to 63° S, and it seems to be several degrees north of the latitude in which easterly and westerly winds are equally prevalent. The path of the cyclonic movement in the western part of the Weddell Sea is shown by the drifts of the 'Endurance', and the 'Deutschland', whilst they were beset in the ice, both of which have been charted by Brennecke (1921, pl. ii). There seems to be only this one movement in the South Atlantic and not the two cyclonic movements shown by Meyer (1923) in 40° W and 30° E. The centre of the cyclonic movement is also about 5 or 6° farther north than shown by Meyer.

In Fig. 11 (p. 191) an attempt is made to show approximately the boundary between the water from the Bellingshausen Sea and that from the Weddell Sea. It must be remembered, however, that along the boundary there is certain to be considerable mixing between the two waters, since they are so similar, and the position of the boundary will vary from the mean approximately indicated in Fig. 11. Each season's observations must be examined separately when a more accurate position is needed, and a position decided from the small differences between the two waters which will be described later in this report (p. 198). South Georgia lies in the path of both currents and is influenced to a certain extent by both of them. The Bellingshausen Sea water is predominant west of the island, and the Weddell Sea water east of it. North of the island there is Weddell Sea water with some Bellingshausen Sea water and south of the island a greater proportion of Bellingshausen Sea water.

EXTENT OF THE ANTARCTIC ZONE

The Antarctic convergence, which is the northern limit of Antarctic surface water at the surface, is usually sharp and well defined. It is distinguished by a sudden change in the surface temperature of the sea when it is crossed. From south to north in winter the temperature increases suddenly from about 1 to 3·5° C. and in summer from about 3 to 5·5° C. The continuous temperature record on the left-hand side of Fig. 10 shows a drop of surface temperature from 3·2 to − 0·2° C., registered when the Antarctic convergence was crossed from north to south: it represents a sharp convergence. Occasionally, and especially if the convergence is crossed obliquely, we have found that it is not straight, and the ship passes through cold and warm patches of water alternately. This has been noticed particularly after bad weather, when the speed and direction of the surface pure drift currents will have been varying considerably. It is, however, found that there is always either a sharp convergence or these patches, and never a gradual change from one kind of water to the other. The convergence is usually not very well defined in the bend to the west in about 50° W, nor in the northerly bend to the north of South Georgia, and in both places there is a tendency for sub-Antarctic

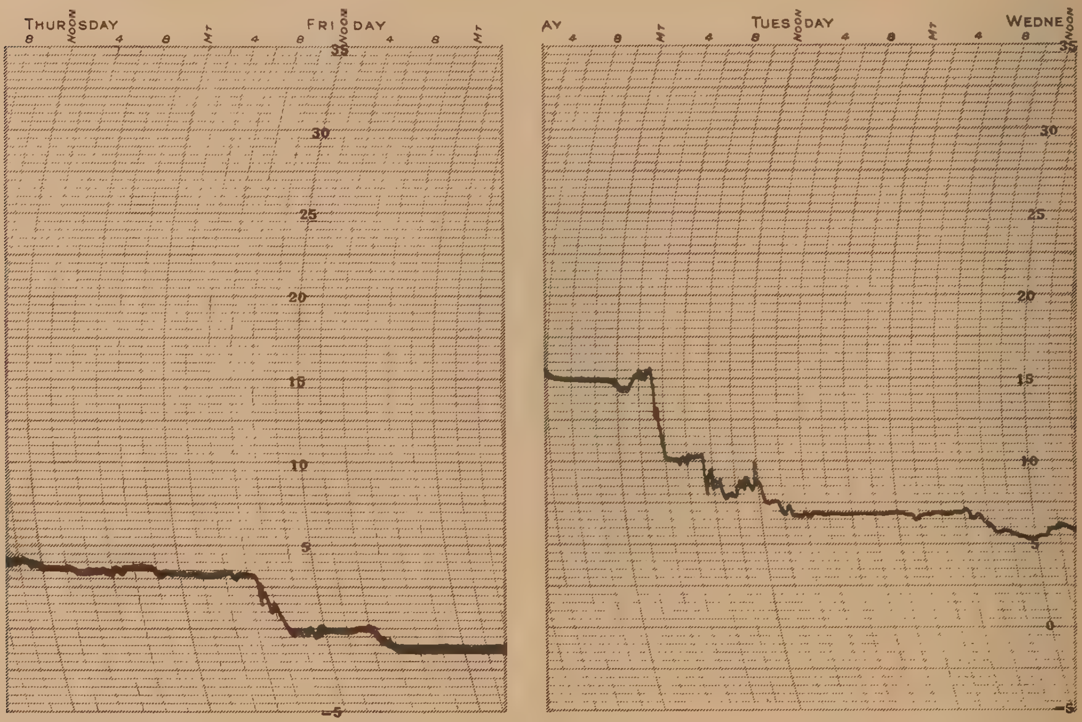


Fig. 10. Thermograph records showing the sudden change in temperature at the Antarctic (left) and sub-tropical (right) convergences (vertical scale in ° C.).

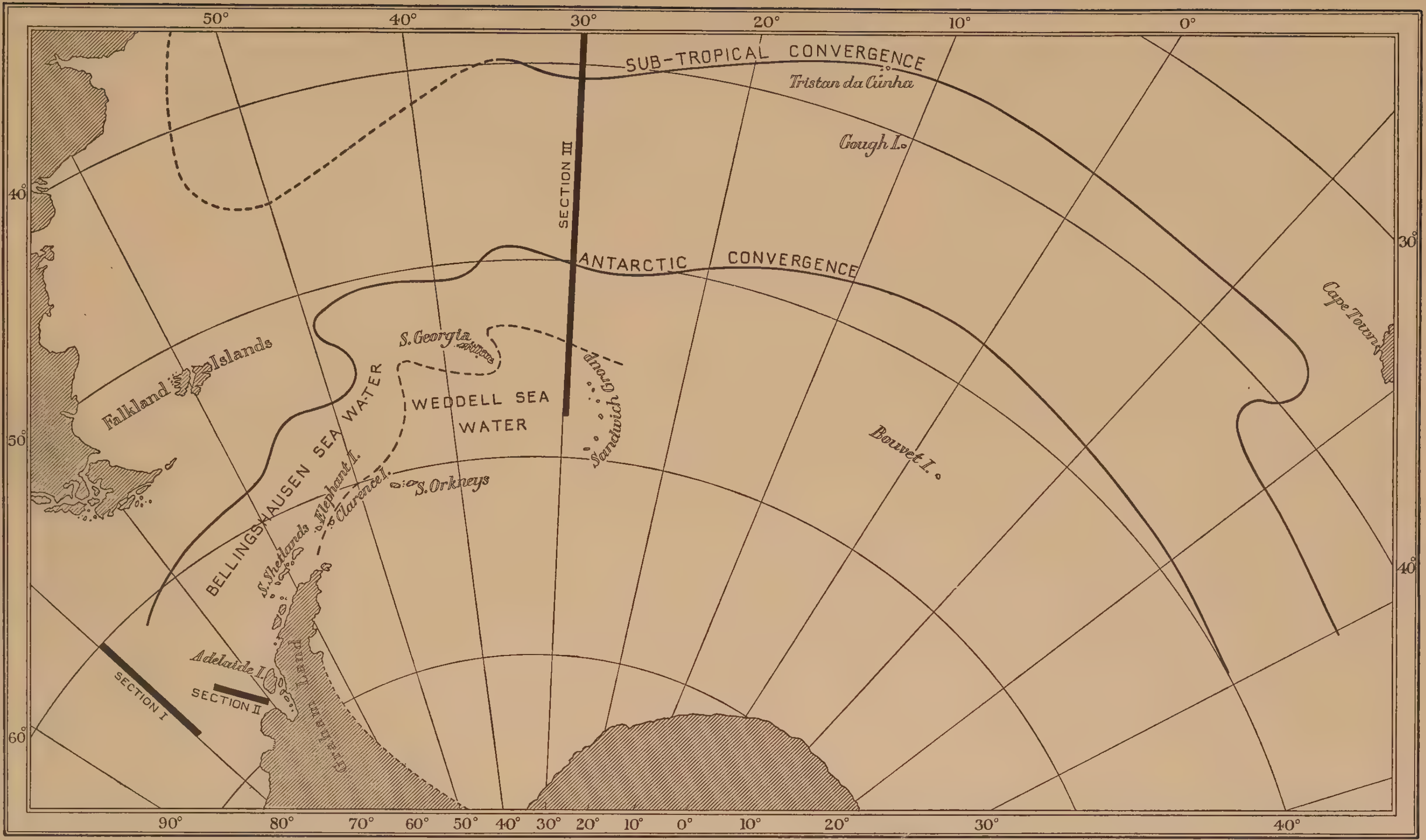

SUB-TROPICAL CONVERGENCE
ANTARCTIC CONVERGENCE
Tristan da Cunha
Gough I.
Cape Town
Bouvet I.
SECTION III
S. Georgia
Sandwich Group
WEDDELL SEA WATER
BELLINGSHAUSEN SEA WATER
Falkland Islands
S. Orkneys
Clarence I.
Elephant I.
S. Shetlands
Graham Land
Adelaide I.
SECTION II
SECTION I
50°
40°
30°
20°
10°
0°
90°
80°
70°
60°
50°
40°
30°
20°
10°
0°
10°
20°
30°
40°
40°
50°
60°
30°
40°

Fig. 11. The Antarctic and sub-tropical convergences, the boundary between Weddell Sea and Bellingshausen Sea waters. Heavy lines show the positions of sections I, II, and III.

surface water to move eastwards across the convergence. According to the evidence which has been obtained so far, the position of the convergence does not vary very much, certainly not more than 60 miles between its extreme positions, although the temperature and salinity of the water sinking into the sub-Antarctic layer vary considerably. The position of the Antarctic convergence shown in Fig. 11 has been obtained from the position of the sudden change in surface temperature or from the position at which the temperature minimum in the cold stratum of the Antarctic surface layer sinks below 200 m. The two positions are usually about the same; but in the two bends of the convergence which have just been mentioned, a strong flow of sub-Antarctic water is sometimes found at the surface, whilst the cold stratum of the Antarctic surface layer has not sunk. The surface conditions in these places are thus sub-Antarctic, and are probably only temporary, whilst only about 100 m. below the surface there is still Antarctic water and its presence is permanent. The latitude of the Antarctic convergence for longitudes between 80° W and 30° E is shown in the following table.

Table I

Latitude	80° W	75° W	70° W	65° W	60° W	55° W
Longitude of Antarctic convergence	62° 40′ S	60° 30′ S	59° 30′ S	58° 40′ S	58° 20′ S	55° 50′ S
Latitude	50° W	48° W	45° W	40° W	35° W	30° W
Longitude of Antarctic convergence	55° 50′ S	55° 30′ 53 10′ 51 10	50° 30′ S	51° 00′ S	49° 30′ S	50° 10′ S
Latitude	25° W	20° W	15° W	10° W	5° W	0°
Longitude of Antarctic convergence	50° 30′ S	49° 40′ S	48° 40′	48° 00′	47° 40′	47° 40′
Latitude	5° E	10° E	15° E	20° E	25° E	30° E
Longitude of Antarctic convergence	48° 00′	48° 30′	48° 50′	49° 10′	49° 40′ S	50° 10′ S

The sudden rise in surface temperature was first noticed by Meinardus (1923, p. 531 *et seq.*), who explained the convergence as the line along which the ice water spreading northwards sinks below the surface. He gave a table (p. 544) showing the latitude of the convergence from 105° W to 80° E which is not much different from Table I. The convergence was next described by Schott (1926, p. 241) in the South Atlantic Ocean, who called it the "Meinardus Line". It has since been described by Wüst (1928, p. 518) and Defant (1928, p. 475). Both authors call it the "Oceanic Polar Front", and base its position on a chart of the surface currents in the Atlantic by H. H. F. Meyer (1923). They give its position correctly between 50° W and 10° E, but between 40 and 60° W they have confused it with the sub-tropical convergence between the Falkland current and the Brazil current. We have used the name ANTARCTIC CONVERGENCE, which means the line of the convergence of Antarctic and sub-Antarctic waters.

The Antarctic Zone extends northwards from the Antarctic Continent to the Antarctic convergence, and includes islands which have been considered from climatic reasons to be sub-Antarctic. The only logical subdivision of the zone on hydrological grounds is into two regions. In the first of these the surface water is part of the westerly drift south of 66° S, or has its origin in this drift and is not far removed from it: in the second it is part of the drift towards the east in the region of westerly winds. In the Falkland Sector this subdivision separates regions affected by Weddell Sea water and Bellingshausen Sea water. Over the whole zone, however, the layer of Antarctic surface water is continuous: it is deepest in the north and shallowest in the south.

There is already considerable evidence of the importance of the Antarctic convergence as a boundary in the distribution of marine plankton. There are some species which are confined to waters to the south of it and others which are found only north of it. At least one species has been shown to have different broods north and south of the convergence, with only such mixing between the two as can be explained by some of the Antarctic brood being carried northwards in the sinking Antarctic water, and some of the sub-Antarctic brood being carried southwards in deeper water. The Antarctic convergence is probably the extreme northerly limit of pack-ice; but pack is rarely found so far north. Ice will stop at the convergence because there is a smaller movement northwards in sub-Antarctic water than there is in Antarctic water, and because of the sudden increase of temperature.

Judged from a hydrological standpoint the Falkland Island Dependencies are all Antarctic, although the Falkland Islands themselves are sub-Antarctic. Farther east Bouvet Island, Heard Island, and MacDonald Island are Antarctic. Kerguelen lies just on the convergence and there is a mixture of Antarctic surface water and sub-Antarctic water near it. Marion and Prince Edward Islands, the Crozets and Possession Island, are just north of the convergence, but so close to it that the Antarctic surface water has not had time to sink far below the surface. When water upwells, as it will do particularly on the north side of the islands, their hydrological conditions and marine life will be influenced by Antarctic water, as well as by sub-Antarctic water.

DEPTH OF THE ANTARCTIC SURFACE LAYER

It has already been mentioned that between the Antarctic surface layer and the warm deep water there is a well-defined discontinuity in the change of temperature and salinity with depth. This indicates the presence of well-defined layering which hinders vertical mixing, but there must be a small amount of mixing taking place, especially in winter. The level at which the temperature, salinity and density change most rapidly with depth can be considered the boundary between the two layers. It has been found that the changes are greatest about 40 m. below the depth of the minimum temperature of the cold stratum of the Antarctic surface layer, and it is also at about this depth that the temperature is the mean of the minimum of the cold stratum and the maximum of the warm deep water. It is in this way that the depth of the layer has been measured.

The depth of the layer varies with the speed and direction of the surface currents. The influence of the earth's rotation on the layers of equal density in a current is to make them slope downwards to the left of the current in the southern hemisphere. The depth of the discontinuity is therefore greater on the left-hand side of a current, and less on the right and for this reason the depth of the layer changes within the zone. The effect is greatest in the neighbourhood of land masses because the layers slope more steeply when the inflow of water laterally into the current is prevented. In the centre of a cyclonic movement, clockwise in the southern hemisphere, the layer is shallowest and the deep water nearest to the surface. In the centre of an anticyclonic movement the layer will be deepest.

Besides the variation in depth caused by the difference in the surface currents there is a general increase from south to north from about 100 to 250 m., and this is probably explained by the relative densities of the surface and deep layer and their movements. Although the Antarctic surface water sinks suddenly at the convergence there is a gradual sinking from south to north in the layer and also a rise in the deep water below it in the opposite direction. There is also some variation in the depth of the layer as a result of internal waves in the sea which have been shown to give a small vertical oscillation to layers of equal density.

TEMPERATURE AND SALINITY OF THE ANTARCTIC SURFACE WATER

An examination of salinity sections, such as Fig. 4, which have been made near the edge of the ice or near to the land in summer, shows how great is the influence of additions of fresh water to the layer. At St. 587 (Fig. 4) there is a low salinity of 32·72°/₀₀ at the surface, and still lower values are occasionally obtained closer to ice or land. At most stations made far south in summer there is a surface stratum 20 or 30 m. thick which contains such water with a very low salinity. A sharp discontinuity in the change of salinity with depth separates this stratum from the rest of the Antarctic surface layer below it, in which the conditions are not much different from those in winter. Later in the season, or farther north, the sharp discontinuity becomes destroyed by vertical mixing and the change in salinity from the surface stratum to the colder stratum is more gradual.

In the south, at least in summer, the winds are not so strong as they are farther north and the low salinity stratum is stable. Because of its stability and the absence of vertical mixing between it and the water below, it does not pass on to the deeper water the heat which it receives by radiation and conduction at the sea surface. The temperature of the stratum therefore rises rapidly and a discontinuity also appears in the change of temperature with depth—a factor which still further increases the stability of the stratum. As water is added to the stratum it will flow away towards the north rather than sink: a stream will flow away from the ice, or in the direction of the surface current which is maintained by other additional influences.

On a very fine day, and especially in sheltered waters, a discontinuity may appear in the surface layer due to the effect of temperature alone. Such a discontinuity is illustrated by observations made at St. 606. At this station the temperature decreased rapidly from 3·30° C. at the surface to 1·84° C. at a depth of 5 m., and to 1·00° C. at 10 m. The salinity at 5 m., 33·89 °/₀₀, was 0·02 °/₀₀ greater than that at 10 m., but 0·01 °/₀₀ less than the surface salinity, which had probably been increased by evaporation. Owing to the almost complete absorption of the sun's radiation near the surface there was a difference of 2·30° C. in temperature, and 0·19 in σ_t, between the water at the surface and that at a depth of 10 m., whilst the salinity was almost the same. Shallow discontinuities and very thin surface strata are often found on fine days in the vicinity of icebergs or pieces of drift ice. Sudden jumps of as much as 4° C. in surface temperature have been recorded by the continuous thermograph when such patches have been crossed. Such thin surface strata do not last, and are only found on calm sunny days. They break up, and help to reduce the salinity and increase the temperature of the surface layer.

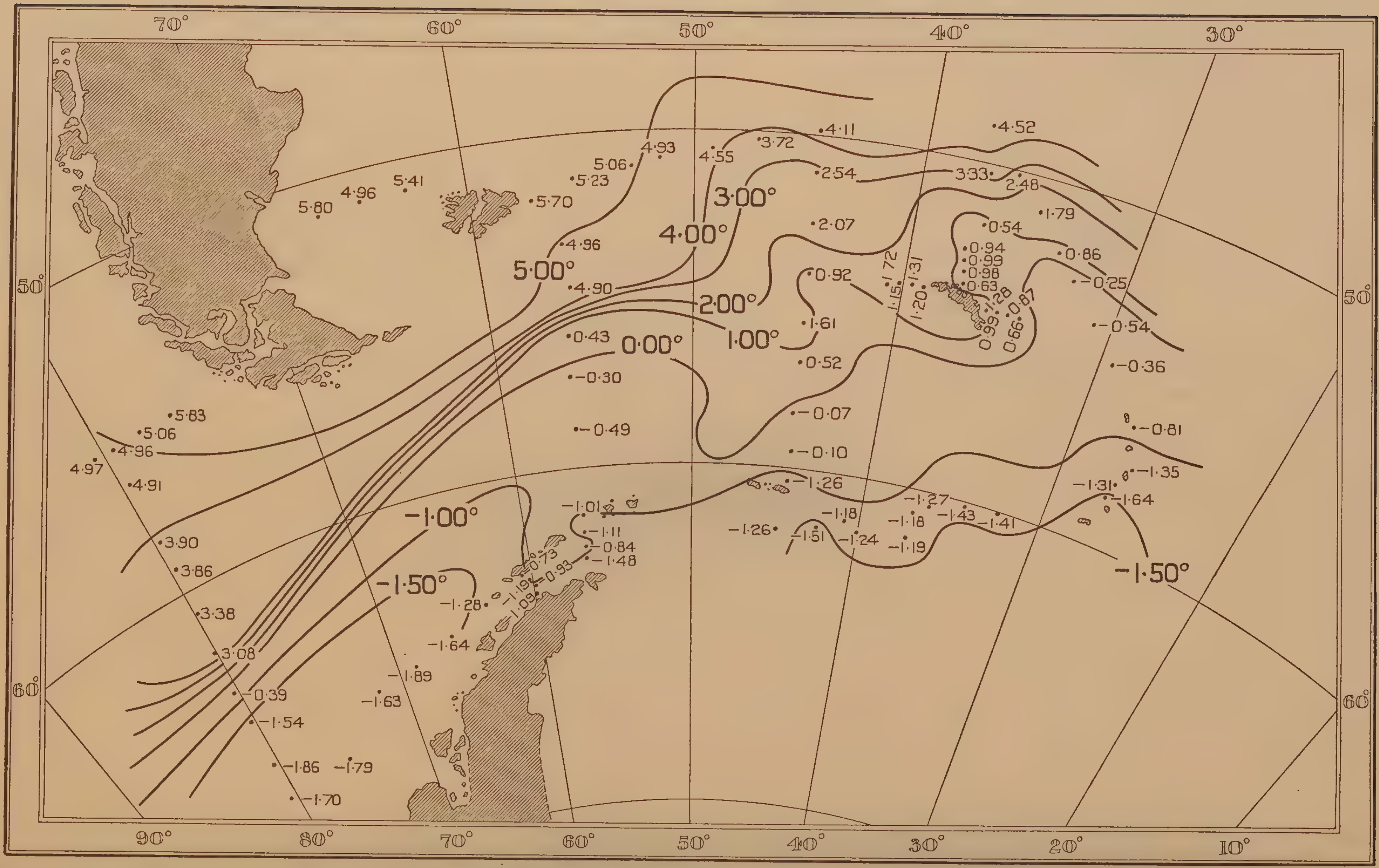
To show the distribution of temperature and salinity in the surface layer in the Falkland Sector, charts have been prepared giving the average temperature and salinity of a surface stratum 100 m. deep. They are based on a survey which was completed in seven weeks, between October 25 and December 13, so that they are not appreciably distorted by the changes which had been taking place whilst the work was being carried out. The distribution of temperature and salinity in the Falkland Sector for different seasons of the year and for different years will be published later, when allowance has been made for such changes. The isotherms are shown in Fig. 12.

The cold water west of Graham Land belongs to the Bellingshausen Sea current. On the northern side of the current the sea is warmer, and the temperature rises slowly until there is a jump of about 3° C. at the Antarctic convergence. The path of the current can be followed by the low temperatures to which it gives rise north of Elephant Island. The cold water east of Graham Land belongs to the Weddell Sea current. The temperatures observed in Weddell Sea water were not so low as those recorded in Bellingshausen Sea water: in the Bellingshausen Sea the temperature at the edge of the pack-ice was $-1{\cdot}63$ to $-1{\cdot}89$° C., and in the Weddell Sea $-1{\cdot}19$ to $-1{\cdot}51$° C. The northerly movement of Weddell Sea water is shown by the low temperature of the eastern half of the Scotia Sea. The bend of the isotherms east of South Georgia shows how Weddell Sea water flows round the north-east coast.

The shape of the 1° and 2° isotherms shows approximately the path of the Bellingshausen Sea water north of the Scotia Sea. Near the western end of South Georgia the isotherms bend southwards, so that the south and west of the island are influenced by this warmer water which has its origin in the Bellingshausen Sea and has been warmed on its way northwards.

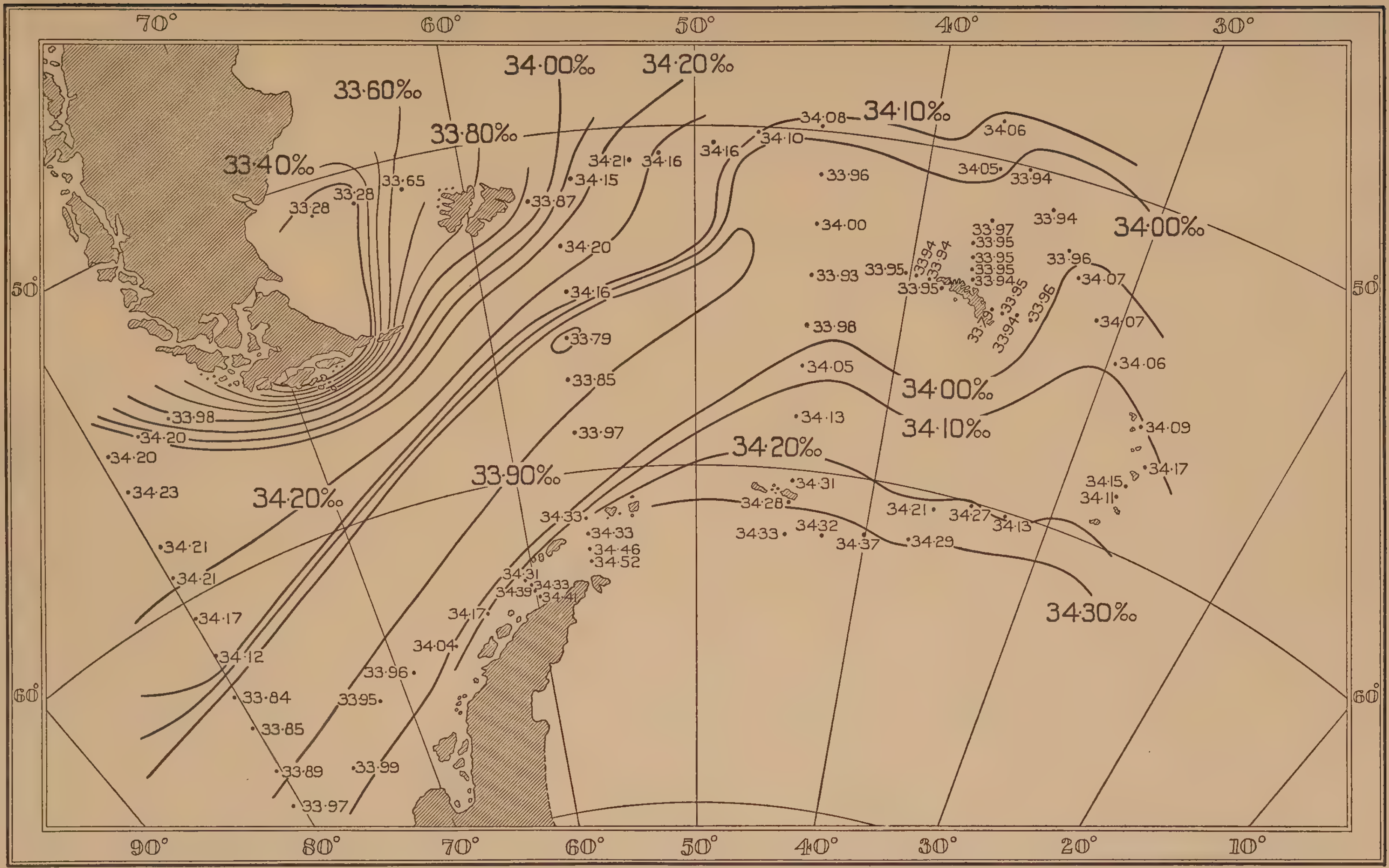
The Antarctic convergence in November follows approximately the 3° C. isotherm in the west; it lies where the 1°, 2°, and 3° isotherms crowd together in the Drake Passage. Farther north, where the convergence is not so sharp, it follows the 3·5° isotherm and lies between the 3° and 4° isotherms. The total range of the average temperature of a surface stratum 100 m. deep, which in November is almost uniform, is from $-1{\cdot}86$° C. in Bellingshausen Sea water to about 3·5° C. at the Antarctic convergence north of South Georgia.

The salinity of the 100 m. surface layer is shown in Fig. 13. It is reproduced principally to show the difference in salinity of the Bellingshausen and Weddell Sea waters. The lowest salinities are those on the northern side of the Bellingshausen Sea current, and the diagram indicates that a belt of water of low salinity exists just south of the convergence. The salinity of the water in this belt of minimum salinity decreases from about 34·84 ‰ in 80° W to 33·79 ‰ farther to the north-east, where the current has



70°
60°
50°
40°
30°
50°
60°
90°
80°
70°
60°
50°
40°
30°
20°
10°
5·00°
4·00°
3·00°
2·00°
1·00°
0·00°
−1·00°
−1·50°
−1·50°

Fig. 12. The temperature of a surface stratum 100 m. deep in the Falkland Sector (° C.).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34·12
33·84
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33·89
33·97
33·99
33·95
33·96
34·04
34·17
34·31
34·39
34·33
34·41
34·33
34·33
34·46
34·52
34·28
34·31
34·33
34·32
34·37
34·29
34·21
34·27
34·13

Fig. 13. The salinity of a surface stratum 100 m. deep in the Falkland Sector.

received more additions of fresh water. In the eastern half of the Scotia Sea the salinity of the water is greater because it has its origin in the Weddell Sea. There is still a minimum salinity in the east of the sector just south of the convergence; but it is not so well defined because the salinity of the Bellingshausen Sea water increases after it reaches its minimum in the west of the Sea. Near South Georgia Bellingshausen Sea water is warmer than Weddell Sea water, because it has travelled farther from its source where it is as cold as, or even colder than, Weddell Sea water.

The greater salinity of the Weddell Sea water is probably due to the fact that whilst it has been flowing round the Weddell Sea in the cyclonic movement described above, it has received continual additions of water of greater salinity from the deep water, which upwells in the centre of the movement. In addition, more ice will probably be formed over Weddell Sea water in winter because the sea extends to such high latitudes, and this too will increase the salinity of the water in winter.

To decide the origin of a body of water which is found near South Georgia it is best to rely on charts showing the distribution of temperature and salinity based on data collected at the time. These diagrams will show the greater influence of Bellingshausen Sea water in the west and of Weddell Sea water in the east. The shape of the isotherms and isohalines will show the direction of continuous movements. The lines will approach close together where the boundary between the two waters is well defined and will be farther apart when the waters are well mixed. The water of greater salinity, provided it is continuous with similar water farther east, can be assumed to be Weddell Sea water and the water of lesser salinity to be Bellingshausen Sea water. Also, colder water will be Weddell Sea water and warmer water Bellingshausen Sea water. Further evidence can be obtained from a chart showing the topography of the sea surface based on calculations of the depth of some deep isobaric surface, which can be considered to be horizontal, below it. Such a chart also shows the directions of continuous movements, for these follow approximately the contours on the chart and have velocities which are inversely proportional to the distance of the contours apart.

Fig. 8, which has been used to show the direction of the surface currents in the Falkland Sector, also shows the distribution of temperature over a wider area than that covered by Fig. 12. The shapes of the isotherms are not quite so accurate, since the observations on which the diagram is based were spread over a slightly longer time, November 10–January 10; the surface also is more rapidly affected by changes due to the approach of summer than is a surface layer 100 m. deep. The isotherms are not, however, seriously distorted, and they give additional information about the Weddell Sea current. They show the drift south and west into the Weddell Sea, as well as the direction of the Weddell Sea current flowing out of the sea. The lowest surface temperature found in Antarctic surface water was $-1{\cdot}68°$ C. in the middle of the Weddell Sea, and the highest $3{\cdot}5°$ C. at the convergence north of South Georgia.

Fig. 14 uses data, already employed in Fig. 5, to show the changes which take place in the temperature of the surface layer during the year. It shows the changes at the surface and at depths of 50, 100, and 150 m., and is based on Sts. WS 160, 268, and

342 made in 1928–9: in the diagram there is also a curve which shows the surface temperature changes at Grytviken, in South Georgia. At Grytviken the surface temperature is at a maximum in February and at a minimum in July. In the open sea the maximum and minimum are reached a little later than they are in inshore waters, which react more quickly to seasonal changes: the maximum temperature is probably at the end of February or early in March, and the minimum in August. In summer the temperature in the open sea decreases with depth from 2·45° C. at the surface to 0·17° C. at a depth of 105 m. With the approach of winter the surface is cooled, and in August the surface was found to be colder than the rest of the layer. This is no doubt a temporary phenomenon due to the presence of water of slightly less salinity in the surface, but it shows that warming of the surface had not started at the end of August. Apart from the surface 5 m. the layer is homogeneous down to a depth of 80 m., but it begins to lose its homogeneous nature after November. The surface is warmed first, and in early summer the difference in temperature between the water at the surface and at 50 m. is greatest. By midsummer the layer is warmed down to a depth of about 80 m. and then there is a rapid decrease in temperature from 1·89° C. at 80 m. to 0·31° C. at 90 m. The surface 80 m. is still almost uniform, because of the great amount of vertical mixing which takes place in it during the turbulent movement of the pure drift currents, caused by the wind.

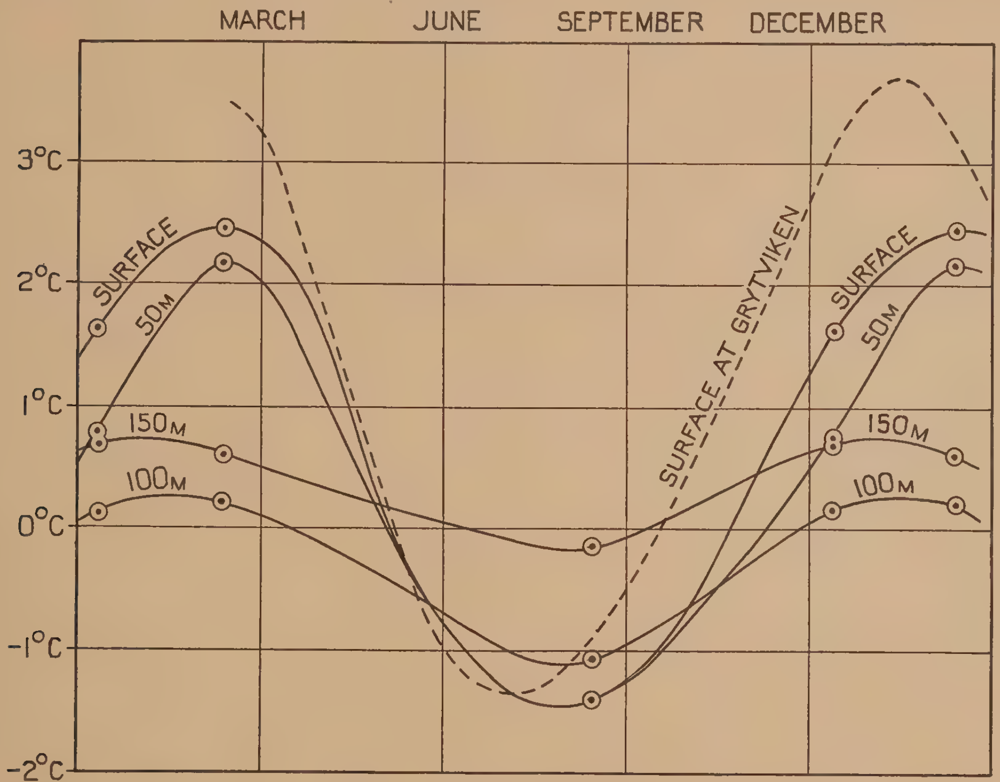


Fig. 14. The seasonal changes in temperature of Antarctic surface water 50 miles north of Prince Olaf Harbour, South Georgia.

The winter and summer temperatures, and the annual range of temperature, at the different levels off South Georgia are shown in Table II.

Table II.

Depth m.	Temperature ° C.		
	Winter	Summer	Annual range
Surface	− 1·40	2·45	3·85
50	− 1·06	2·16	3·22
100	− 1·08	0·19	1·27
150	− 0·15	0·59	0·74

Fig. 15 shows the change of salinity during the year. The surface salinity is greatest in September and least at the end of February. In summer it increases with depth, slowly in the first 50 m., and then more rapidly, especially below 80 m. The difference in salinity between the water at the surface and at a depth of 100 m. is greatest in summer and least in winter. At a depth of 150 m. the minimum salinity is found in winter. This

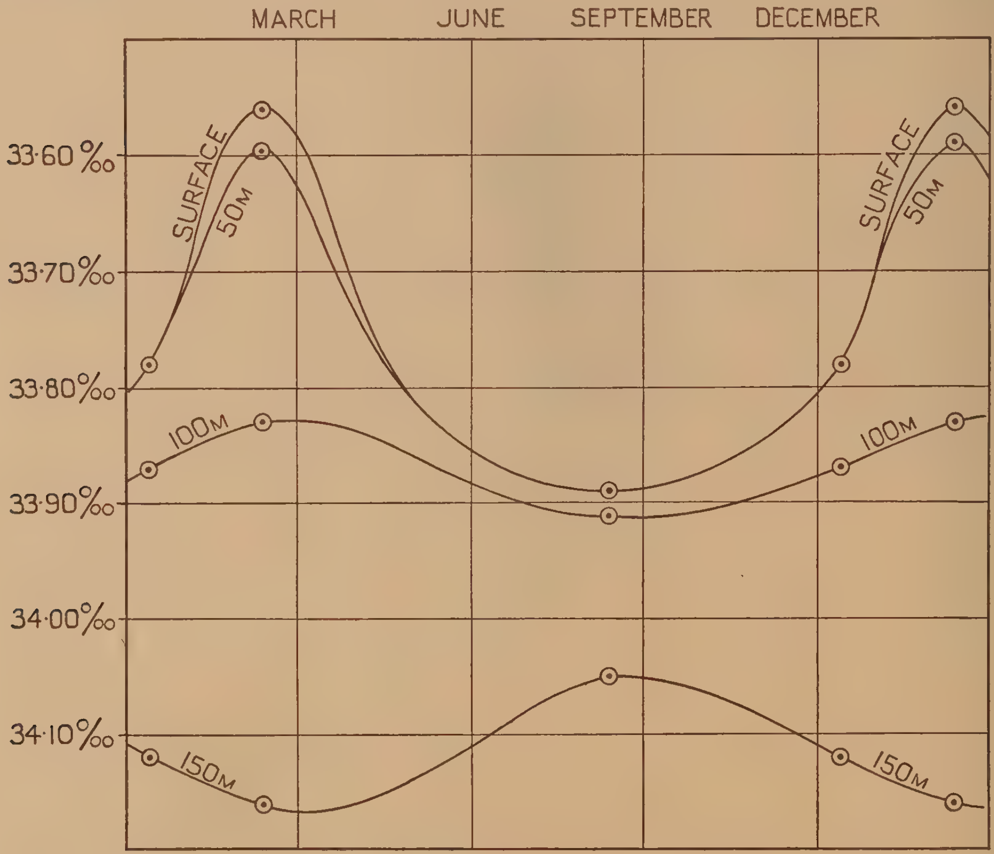


Fig. 15. The seasonal changes in salinity of Antarctic surface water 50 miles north of Prince Olaf Harbour, South Georgia.

is either because the layer is deeper in this particular region in winter, when the surface currents are slower, or because there is a smaller tendency for deep water to upwell.

Fig. 16 shows the seasonal change in density in the surface layer. The Antarctic surface water has its least density at about the end of February, and its greatest density in August and September. In summer the density increases with depth, slowly in the surface 50 m., and rapidly below 80 m.; in winter it is almost uniform down to 100 m.

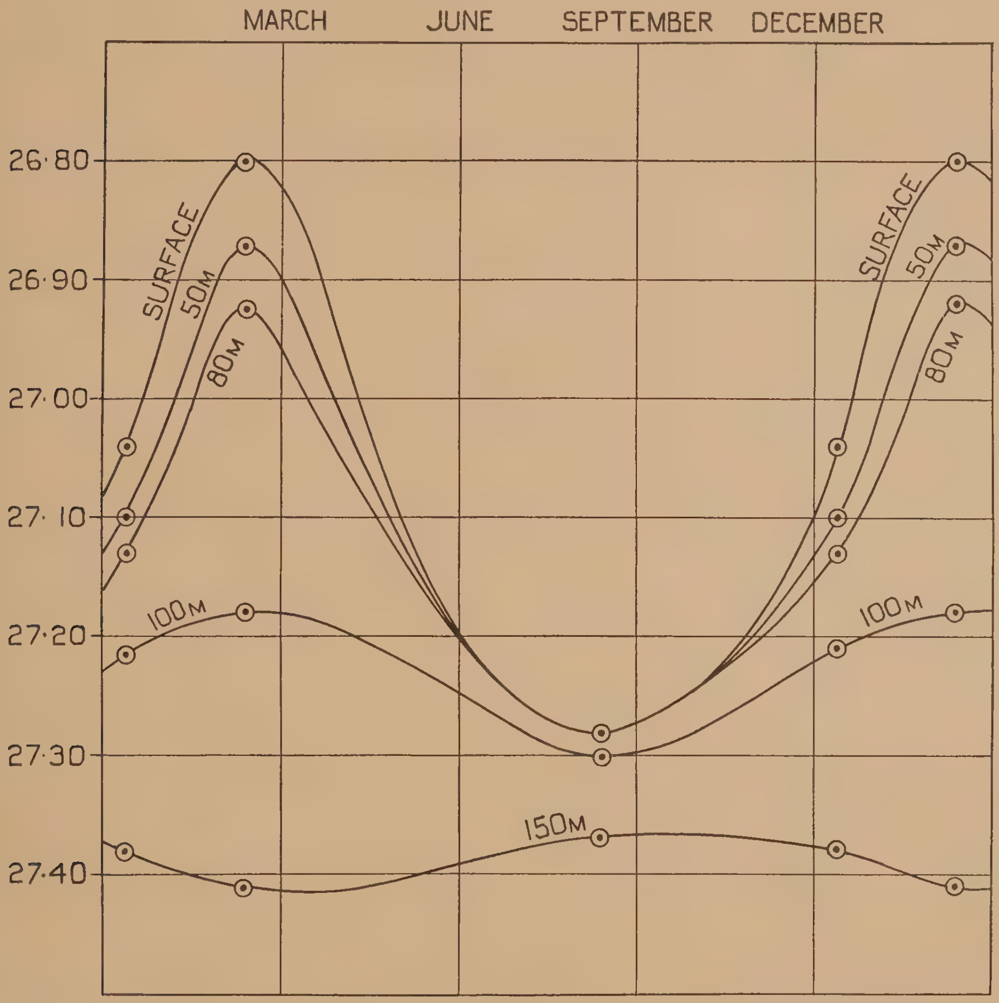


Fig. 16. The seasonal changes in density (σ_t) of Antarctic surface water 50 miles north of Prince Olaf Harbour, South Georgia.

It can easily be seen how such uniformity in winter is brought about. In the two previous diagrams it is shown that the surface 50 m. of water is practically uniform, even in summer. Below 50 m. the changes are slightly greater; but the curves in Fig. 16 show how closely the water at 80 m. is related to the surface water in its properties, and how great is the difference between the 0–80 m. stratum and the rest of the layer. These facts have led to the assumption that the surface 80 m. is affected by pure drift currents, whilst the water below 80 m. is not—an assumption which has been confirmed in sub-Antarctic water by the presence of a component of movement below 80 m. in the opposite direction to the surface transport. With the approach of winter cooling commences in the surface, and its effect is carried into the rest of the surface stratum by the sinking of the surface water as its density increases, and by vertical mixing caused by the turbulent movement of the pure drift currents. The density of the whole of the surface stratum is increased in this way, and also by the inflow of heavier water from the south, until it can hardly be distinguished from the cold stratum and the whole layer becomes almost uniform. The density at 150 m. is least in winter, probably because the layer is deeper at this season.

In Table III the changes in temperature of the Antarctic surface layer from south to north are summarized.

Table III.

Depth	Temperature ° C.	
	In winter	In summer
At the surface	– 1·86 to 1·0	– 1·0 to 3·5
In the cold stratum	– 1·86 to 1·0	– 1·75 to 1·5
At the bottom of the layer	– 1·5 to 1·0	– 1·5 to 2·0

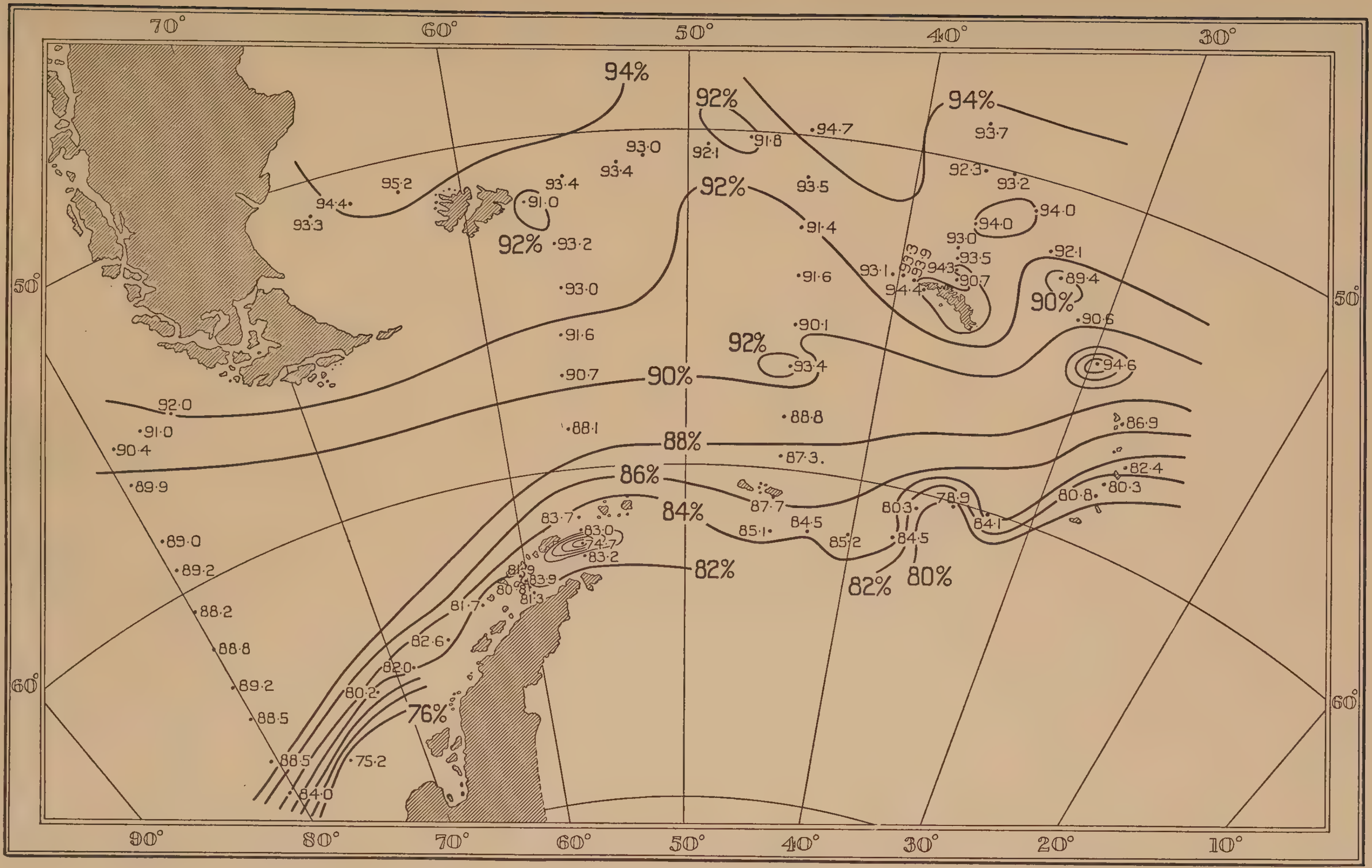
The salinity at the surface can vary enormously, from very low values in the south—in summer when ice is melting—to as much as 34·5 °/₀₀ when ice is forming, or where deep water is upwelling. In the layer as a whole the salinity decreases towards the north, although at the surface the lowest salinities are found near the ice in summer.

OXYGEN CONTENT OF THE ANTARCTIC SURFACE WATER

The oxygen content of the surface 100 m. of water in the Falkland Sector is shown in Fig. 17. The oxygen content is expressed as a percentage of the amount that the water would hold if it were saturated. The diagram shows the conditions in spring before the diatom growth was considerable. The smallest oxygen contents, 75·2 and 74·7 per cent, were found off the west coast of Graham Land and in the Bransfield Strait; low values were also found over the ridge joining Graham Land to the South Orkney Islands and to the South Sandwich Islands. It is probable that pack-ice was present in these localities shortly before the observations were made, and also that the surface water was largely mixed with deep water which had upwelled from below.

The oxygen content of the water increases from south to north. There is also a small increase from west to east in water of the same temperature, about 5 per cent where it is greatest. This may be due to a change which had taken place whilst the survey was being made, or it may be due to a richer phytoplankton growth in the east than in the west.

Fig. 18 shows the vertical distribution of oxygen content in Antarctic surface water


70°
60°
50°
40°
30°
94%
92%
94%
92%
90%
92%
90%
88%
86%
84%
82%
82%
80%
76%
92%
92%
94·7
93·7
91·8
92·1
93·0
93·4
95·2
94·4
93·3
93·4
91·0
93·2
93·5
91·4
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89·4
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90·7
93·1
94·4
91·6
93·0
91·6
90·7
90·1
93·4
90·6
94·6
92·0
91·0
90·4
88·1
88·8
87·3
86·9
89·9
89·0
89·2
88·2
88·8
89·2
88·5
88·5
84·0
75·2
83·7
83·0
74·7
83·2
87·7
85·1
84·5
85·2
80·3
78·9
84·5
84·1
80·8
80·3
82·4
81·7
83·9
81·3
80
82·6
82·0
80·2
50°
60°
50°
60°
90°
80°
70°
60°
50°
40°
30°
20°
10°

Fig. 17. The percentage of saturation with oxygen of a surface stratum 100 m. deep in the Falkland Sector.

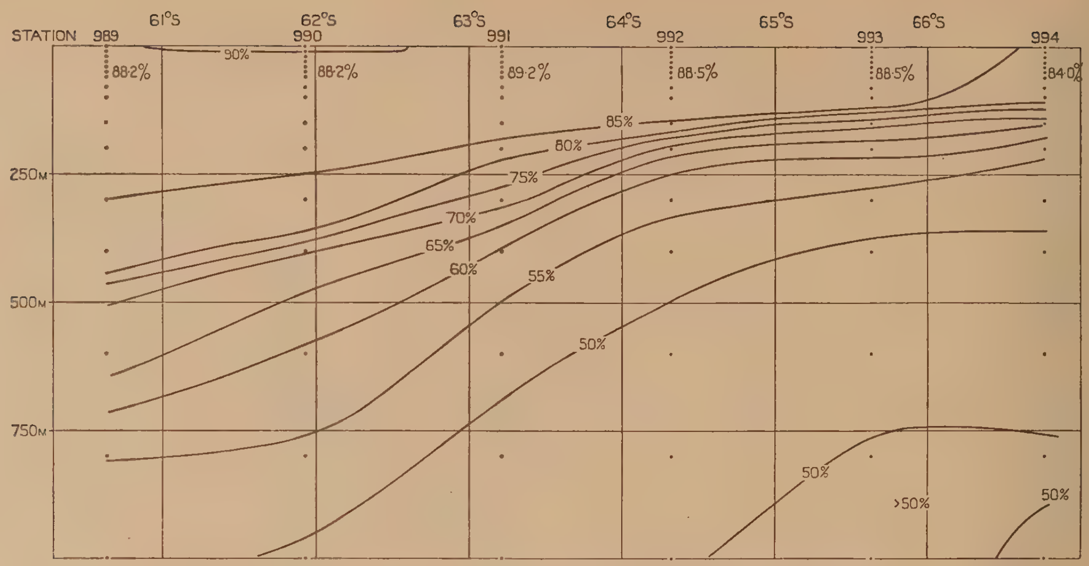

Fig. 18. Section I, distribution of oxygen content (percentage of saturation).

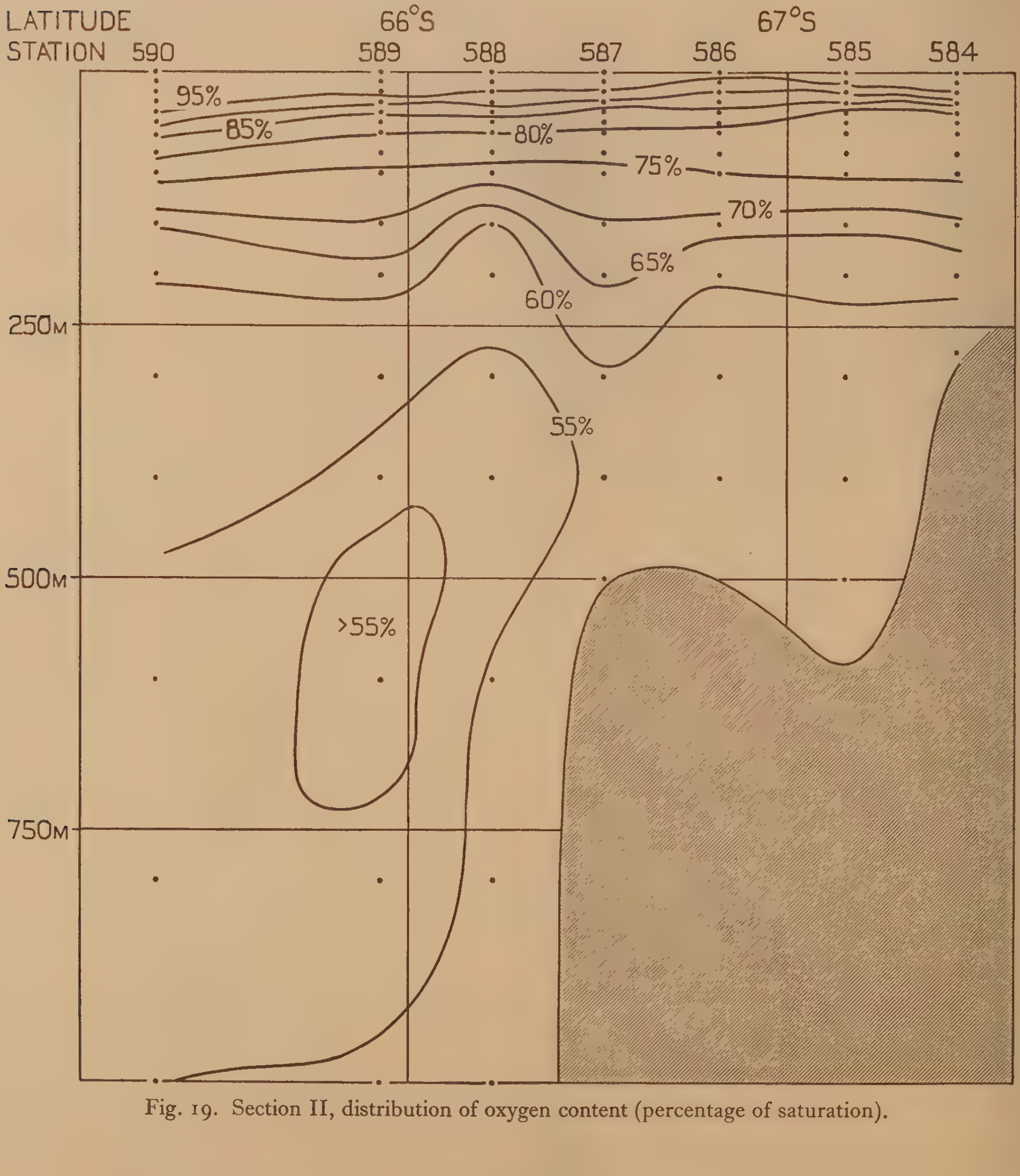

Fig. 19. Section II, distribution of oxygen content (percentage of saturation).

in winter along section I. It shows that apart from the station farthest south, which is influenced by upwelling deep water, the oxygen content of the surface 100 m. is about 88·5 per cent in the south and 89·2 per cent near the convergence: there is also very little difference between the content of the surface water and that at 100 m. Fig. 9 shows the vertical distribution along section II in summer. The oxygen content at the surface is greater than it is in winter; it varies from 96·5 to 99·9 per cent, and it decreases with depth. The content of the cold stratum in section II is less than that in section I, but the difference is due to the greater upwelling of deep water in section II.

Near South Georgia, in January, surface water has been found to be supersaturated with a content as great as 110 per cent. At the same time large catches of diatoms were obtained, and the water had a high *p*H value.

PHOSPHATE AND NITRATE CONTENT OF THE ANTARCTIC SURFACE WATER

The amount of phosphate in Antarctic surface water is always large compared with that in the surface of more temperate seas. In winter it has been found that the average phosphate content of the surface stratum of 100 m., calculated from twenty-one stations near South Georgia, was 138 mg. of $P_2O_5/m.^3$ In the following January at a time when large catches of diatoms were being made, the phosphate content was 110 mg. $P_2O_5/m.^3$ These values are probably both rather high, as the samples on which the phosphate determination was made had been stored for some time.

In January and February of 1930 the average content calculated from fifty-seven stations was 82 mg. $P_2O_5/m.^3$; and in November 1930 from forty-nine stations, 89 mg. $P_2O_5/m.^3$ The minimum phosphate content of the sea water close inshore at Grytviken has been found to be about 77 mg. $P_2O_5/m.^3$ in December or January, and the maximum to be about 130 mg. $P_2O_5/m.^3$ in September or October. The inshore results, however, are likely to be increased by the effect of the effluent from the neighbouring whaling station, and decreased by the large amounts of fresh water, containing very little phosphate, which flow into Cumberland Bay. The lowest phosphate content found in the open sea has been about 70 mg. $P_2O_5/m.^3$, and so many measurements have been made that it can safely be said that the phosphate content of Antarctic surface water in the open sea never falls below this figure. There is no evidence of the existence of a secondary maximum of phosphate content in the autumn, such as is recorded in the English Channel, and the 0–80 m. stratum is so well mixed that it is unlikely to occur. Moreover, in the presence of such an abundance of phosphate a small increase in autumn will not cause a second outburst of diatom production.

Antarctic surface water also contains large amounts of nitrate; the lowest nitrate content found has been 290 mg. nitrate + nitrite $N_2/m.^3$ in summer, and the highest about 550 mg. in October–November.

The abundance of phosphate in the Antarctic surface layer is maintained by upwelling from the warm deep layer. This layer in the Antarctic Zone contains at least 140 mg. $P_2O_5/m.^3$ The source of the high phosphate content in this layer will be described later. The high nitrate content of the Antarctic surface layer is probably also maintained by upwelling.

SUB-ANTARCTIC WATER

NATURE AND DEPTH OF THE SUB-ANTARCTIC SURFACE LAYER, AND THE ORIGIN AND MOVEMENTS OF SUB-ANTARCTIC WATER

The surface layer in the sub-Antarctic Zone is a much thicker layer than that in the Antarctic Zone, and it is composed of much warmer water. Its depth increases from south to north, and it is about five times as thick as the Antarctic surface layer. Its surface temperature increases from south to north from about 3 to 11·5° C. in winter, and from 6 to 14·5° C. in summer. It lies entirely within the region of westerly winds, and the water in it flows towards the east in a continuous movement around the Southern Ocean.

Plate VIII shows the vertical distribution of temperature in the layer along 30° W, where the sub-Antarctic Zone extends from 49° 30′ to 40° 30′ S. Between these latitudes the temperature generally decreases with depth down to a level to which the Antarctic surface water has sunk. This level is shown in Plate VIII by the bends in the isotherms towards the north, which indicate the presence of a cold stratum of water continuous with the cold stratum of the Antarctic surface layer. An Antarctic layer will not, however, be distinguished below sub-Antarctic water, since the two are so mixed that it is not possible to decide where one ends and the other begins. The whole layer will be called the sub-Antarctic surface layer, but it is useful to remember that the water in the bottom of the layer is probably more Antarctic in origin than the rest.

Below the cold stratum, which contains the remains of the coldest Antarctic water, the temperature rises owing to the presence of a warm deep layer. This is continuous with the warm deep layer which lies below Antarctic surface water, although all the warm deep water in it is not necessarily of the same origin. In the top of the warm deep layer there is a secondary temperature maximum which is maintained by warm water flowing southwards, and at the bottom of the sub-Antarctic layer a secondary temperature minimum maintained by cold water flowing northwards. Between these two levels lies the boundary between the two layers, and it is sufficiently accurate to assume that it lies half way between them. In 30° W the depth of the sub-Antarctic surface layer is about 1100 m. in 45° S and 1450 m. in 40° 30′ S.

Plate VIII also shows the vertical distribution of salinity in 30° W. In the sub-Antarctic Zone the change of salinity with depth is much less rapid than it is in the Antarctic Zone, but there is still a discontinuity between the sub-Antarctic water and the warm deep water. The discontinuity is not so well defined as that south of the Antarctic convergence, and vertical mixing takes place across it to a greater extent, particularly north of 45° S. Between the surface and 60–80 m. there is a transport to the north as a result of the pure wind drift currents, and it is unusual to find any appreciable change of salinity or temperature with depth. The stratum is uniform because of the vigorous mixing which takes place in the turbulent movements of the drift currents. The total movement in the stratum will be the resultant of the pure wind drift current and the deep current; and at the surface, it is shown by all the available current charts to be a little north of east.

The winds of the Atlantic Ocean south of 40° S are described by Lieut. R. A. B. Ardley, R.N.R., in the Appendix to this report. The resultant strength of the westerly winds—their average strength multiplied by their frequency—in different latitudes is shown in Table XII, column 4 (p. 236). This resultant is greatest between 45 and 50° S, and the percentage of easterly winds is also least between these latitudes. The surface transport towards the north due to wind influence will therefore be greatest between 45 and 50° S, and it will decrease towards the north. Because of this there will be a tendency for the surface water to sink towards the north, and also, in the south of the zone, for water to well up towards the surface. Below the surface stratum the movement in the layer is towards the east in a deep current which is the result of the westerly wind. But at the same time there are north and south components of movement, and these are responsible for the maintenance of the temperature and salinity distributions which are typical of the layer.

On the western side of the South Atlantic, and particularly outside a region of intense mixing, which reaches about 100 miles north of the Antarctic convergence, there is an increase in salinity with depth below about 80 m. Sometimes the temperature also increases, or there is a decrease in the temperature-depth gradient. A stratum of water of greater salinity is found between 80 and 100 m. at St. 668, in 46° 43′ S; and between 100 and 150 m. at St. 671 in 43° 08′ S. Such a stratum can have a continued existence between waters of lesser salinity only if the water in it has a component of movement towards the south, at least relative to the waters above and below it; but it is not quite certain how such a component can be explained. It may be a return current to compensate for the flow of surface water towards the north in the drift current. This explanation appears the more likely to be valid because in the South Atlantic Ocean north of 45° S the amount of northerly transport decreases towards the north, so that the surface water must sink towards the north. Within 100 miles of the Antarctic convergence there is not so much evidence of this southward movement below 80 m.; this may be due to the greater vertical mixing, or to a falling off towards the south of the northerly transport which might cause the water of the return current to well up towards the surface. On the western side of the South Atlantic, however, the stratum between 80 and 200 m. is more remarkable for its high salinity than its high temperature, and it also has a low oxygen content. If therefore it is composed of water which has sunk below the surface, it must be mixed with water from deeper sources. Just south of the sub-tropical convergence it contains sub-tropical water, and the last traces of this may reach to within 100–150 miles of the Antarctic convergence.

The presence of a southerly component can also be explained as the result of a small thermohaline circulation, confined to the surface 200 m. of sub-Antarctic water and due to the difference in temperature between the climate in the south and north of the zone. The southerly component has been found in the east of the South Atlantic Ocean, but in the east of the Pacific Ocean it is only found near the sub-tropical convergence. It is not confined to sub-Antarctic water, but also appears in sub-tropical water when there is a prevailing westerly wind.

Below 200 m. the water in the sub-Antarctic layer has a component of movement towards the north, except perhaps in the eastern corner of the Pacific Ocean. Near Cape Horn, there is a general component in the layer towards the south, for in this region part of the easterly current across the Pacific is deflected southwards to flow through the Drake Passage.

Conditions in the southern and northern parts of the sub-Antarctic Zone differ rather widely, and the two areas must be considered separately.

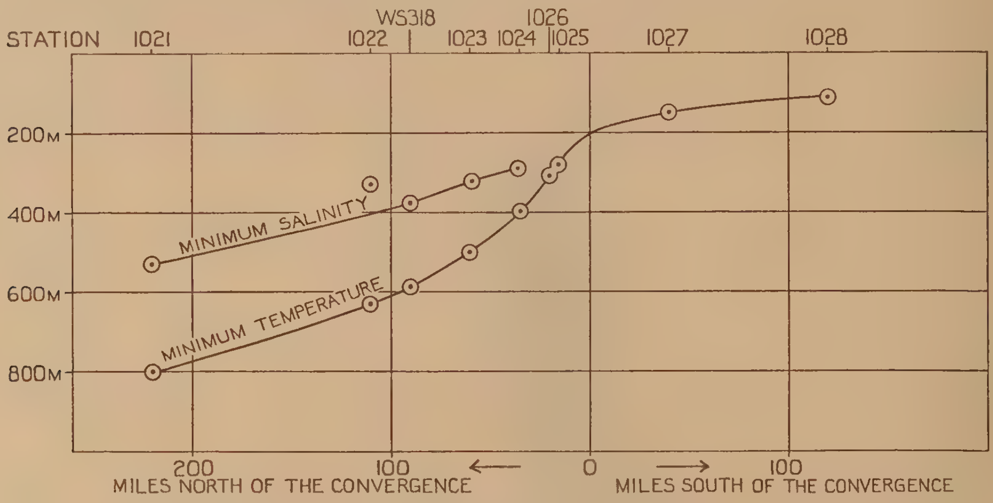

Fig. 20. The depth of the minimum temperature in Antarctic surface water and sub-Antarctic water, the depth of the minimum salinity of sub-Antarctic water.

In the Southern Half of the Zone in the region of intense vertical mixing extending about 100–150 miles north of the Antarctic convergence there are only small changes from west to east. In the Pacific Ocean in 80° W the salinity of the layer is almost uniform with depth down to about 300 or 400 m., or it decreases to a weak minimum at that depth. The temperature is usually uniform down to 150 m. and then decreases gradually. There is sometimes a minimum temperature at the same depth as the minimum salinity, and both are caused by the greater percentage of Antarctic surface water in the mixture of the two waters at that depth. Below the level of minimum salinity the salinity increases, and there are only small temperature changes. At a depth of 600–800 m. the temperature decreases to a minimum, and there is a stratum of comparatively uniform salinity. This is composed of water which has sunk from the cold stratum of the Antarctic surface layer. When the Antarctic surface water sinks below the surface, the water in the cold stratum will be least mixed with sub-Antarctic water, because it is much heavier. The warmed and diluted surface stratum of Antarctic surface water has, however, a density not so different from sub-Antarctic water, and mixes more readily with it. So complete is the mixing in the region extending 100–150 miles north of the convergence, that it is not often that the minimum salinity at a depth of 300–400 m. can be detected. In summer, or at the end of summer, vertical mixing is not so complete, and a surface stratum is usually formed which is similar to that in the Antarctic Zone but not nearly so well defined.

In the Drake Passage, where the components of movement perpendicular to the convergence are restricted by the land masses to the north and south, neither the minimum salinity nor the minimum temperature can be detected. Near Cape Horn the surface is considerably diluted by coastal water.

At stations east of the Falkland Islands both the minimum salinity caused by the Antarctic surface water, and also the minimum temperature caused by the cold stratum of Antarctic surface water, are found. The depth of the minimum temperature is shown in Fig. 20. South of the Antarctic convergence it shows the depth of the cold stratum of Antarctic surface water, and north of the convergence the depth to which the water from the cold stratum sinks. The depth of the minimum salinity north of the convergence is also shown; at this depth there is more water from the surface stratum mixed with sub-Antarctic water.

In the bend of the Antarctic convergence to the east of the Falkland Islands, and also in the bend north of South Georgia (Fig. 11) there appears to be the strongest flow of Antarctic water below sub-Antarctic water and also of sub-Antarctic water eastwards over Antarctic water. In both regions the convergence is never very well defined, and it is the more difficult to fix with accuracy because the rise in surface temperature usually occurs south or east of the position where the Antarctic surface water starts to sink rapidly. A stratum of sub-Antarctic water is often found above a stratum of Antarctic water which is still at its usual depth and conditions in these regions can change suddenly with depth.

In the eastern half of the South Atlantic, particularly south of the Cape of Good Hope, the movement at right angles to the convergence seems to be restricted, as a result of a general southerly component of movement in sub-Antarctic water. Such a component is probably caused by the sub-Antarctic water being driven southwards to round the Cape and the southerly extension of sub-tropical water caused by the Agulhas current. As a result the minimum salinity is not found except at a greater distance north of the convergence, and the minimum temperature is not well defined.

The mixture of water which results from the addition of Antarctic surface water to the sub-Antarctic water moves towards the east, and at the same time sinks towards the north. Its path is shown by the depth of the levels of minimum temperature and minimum salinity which can be followed a long way north in the Atlantic—the minimum salinity as far north as 25° N. This movement will be described in the section on the Antarctic intermediate water.

In the NORTHERN HALF OF THE ZONE there is a surface stratum 60–80 m. thick in which the salinity and temperature are almost uniform with depth. Below this surface stratum, the salinity increases until it reaches a secondary maximum value between 80 and 200 m., where there is a movement southwards. The temperature starts to fall rapidly immediately below the surface stratum, but its decrease is arrested somewhat, and occasionally is changed to an increase between 80 and 200 m. Below this stratum the temperature and salinity both decrease rapidly until more uniform water is reached near the level of minimum salinity between 400 and 600 m. Their decrease is then less rapid. Below the level of minimum salinity the salinity increases rapidly, but the temperature continues to decrease slowly until the level of minimum temperature is reached, between 800 and 1200 m. In this level, too, the change of salinity with depth becomes slightly less. Below the level of minimum temperature both the temperature and salinity increase, the temperature to a secondary maximum value in the upper stratum of the warm deep layer, and the salinity to a maximum deeper down in that layer.

The origins of sub-Antarctic water can be summarized as follows:

(1) In Antarctic surface water which sinks below the surface at the Antarctic convergence; and, to a much smaller extent, in Antarctic surface water which mixes across the Antarctic convergence at the surface.

(2) From the heavy precipitation in the sub-Antarctic Zone which exceeds the amount of evaporation by about 700 mm. per annum, and also from coastal waters.

(3) In additions from the sub-tropical surface layer between 80 and 200 m., and also by mixing across the sub-tropical convergence at the surface.

The effect of mixing across the sub-tropical convergence will be described in the next section.

EXTENT OF THE SUB-ANTARCTIC ZONE

The sub-tropical convergence, which is the northern boundary of the sub-Antarctic Zone and the convergence of sub-Antarctic and sub-tropical waters, is not so well known as the Antarctic convergence. It is, however, usually a much sharper convergence, and is marked by a sudden change of surface temperature of at least 4° C., and a change of salinity of at least 0·50 °/₀₀. A continuous temperature record showing the sudden fall in surface temperature on crossing the subtropical convergence is shown on the right-hand side of Fig. 10 (p. 190). At the convergence sub-Antarctic water sinks below the surface. It does not sink downwards to the north because between 80 and 200 m. sub-tropical water is moving southwards into sub-Antarctic water. Instead, it must mix with the water in this movement, and then, on its way southwards it either mixes again with the deeper water moving northwards, or wells up towards the surface.

To explain the sharp convergence at the surface that is almost always encountered, there must be a much greater movement northwards in the surface of sub-Antarctic water than there is in sub-tropical water. The sub-tropical convergence is still within the region of westerly winds, but since it is found in about 40° S the winds are much weaker north of it. The convergence can therefore be explained as a result of the greater transport of water towards the north in the surface stratum of sub-Antarctic water; but this reason is not sufficient to explain the sharpness of the convergence, since the falling off of wind strength is gradual.

South of the Brazil current and the Agulhas current there is a southward movement at the surface which is probably stronger than the transport of water northwards due to wind currents, and south of these two currents the convergence lies farthest south. In 30° W the salinity and temperature distribution show that there is a southward movement below 80 m.: if such a movement also occurs at the surface it is reduced by the effect of the wind. In mid-ocean the convergence is farther north; it is not so far removed from the region of the south-east trade winds, which give rise to a water transport in the surface towards the south-west.

When the sub-tropical convergence is crossed, and especially when it is crossed obliquely, it has been noticed that there are large areas of sub-tropical water cut off by sub-Antarctic water, and the ship passes through patches of sub-tropical and sub-Antarctic water alternately. When a station is made in such a patch of sub-tropical water, it is found to be lying above sub-Antarctic water in a layer about 200 m. deep, but when the patches of sub-Antarctic water are examined they show the changes of temperature and salinity with depth which are typical of the sub-Antarctic Zone. It is therefore the sub-tropical water which pushes southwards over the convergence to cause these isolated patches of water. These patches are formed so extensively south of the Brazil current and the Agulhas current that it is impossible to fix the convergence definitely; but an attempt has been made in Fig. 11 to show the convergence as the northern extent of sub-Antarctic water. South of the Cape of Good Hope it is most likely that sub-Antarctic water will not be encountered north of the position shown, but south of the Brazil current there is not enough information to be certain even of this. The latitude of the convergence between 50° W and 30° E, based on our own observations, is given in the following table.

Table IV

Longitude	50° W	45° W	40° W	35° W	30° W	25° W
Latitude of sub-tropical convergence	44° 30′ S	43° 30′ S	41° 30′ S	40° S	40° 30′ S	39° 30′ S
Longitude	20° W	15° W	10° W	5° W	0°	5° E
Latitude of sub-tropical convergence	38° 30′ S	37° 30′ S	37° S	37° S	37° S	37° 30′ S
Longitude	10° E	15° E	16° E	20° E	25° E	30° E
Latitude of sub-tropical convergence	37° 30′ S	37° 30′ S	37° 30′ S 41° S 42° 30′ S	43° S	43° 30′ S	44° S

When a station is made near the convergence, the salinity and temperature of the water must be used to decide whether the water is sub-tropical or sub-Antarctic, or how much the two waters are mixed.

The sub-Antarctic Zone includes Cape Horn, and the Falkland Islands, and as much of the Patagonian coast as is influenced by the Falkland current which flows as far north as the River Plate. Gough Island is sub-Antarctic, and Tristan da Cunha is just sub-Antarctic. The Cape of Good Hope is north of the sub-tropical convergence, but the cold water off the south-west coast of Africa is water which has upwelled from the Antarctic intermediate layer into which sub-Antarctic water sinks. The conditions off the south-west coast are therefore partly sub-Antarctic as well as sub-tropical. Off the south and east coasts the water is sub-tropical, and in summer it is almost tropical owing to the influence of the Agulhas current.

TEMPERATURE AND SALINITY OF THE SUB-ANTARCTIC WATER

Both the temperature and salinity of the sub-Antarctic water increase towards the north. The increase is greatest between 80 and 200 m., as would be expected if the water in this stratum was flowing southwards as well as eastwards and losing its heat and salt content by mixing. It is next greatest in the surface stratum, in which the water has a component of movement to the north. The changes are least at the level of minimum salinity, where a large volume of water is sinking towards the north; and they are least because the properties of a large volume do not change readily. At the level of minimum temperature, and at the bottom of the layer, there is a considerable increase in salinity towards the north because of the mixing which takes place with the warm deep layer.

The surface temperature of sub-Antarctic water just north of the Antarctic convergence in the West Atlantic Ocean is about 3 to 3·5° C. in winter and 6° C. in summer. It increases from south to north, slowly in the southern half of the zone and more rapidly in the northern half, where vertical mixing is not so complete. Near the sub-tropical convergence the surface temperature is about 11·5° C. in winter and 14·5° C. in summer. The salinity in the south of the zone varies between about 33·95 °/₀₀ at the end of summer and about 34·10 °/₀₀ at the end of winter. The salinity also increases towards the north. Just south of the sub-tropical convergence it has a value of about 34·4 °/₀₀, but it may be much increased south of the Brazil current and south of the Agulhas current, by mixing with sub-tropical water which has crossed the convergence at the surface. In the east of the Atlantic Ocean the surface stratum has a lesser salinity than in the west, probably because of the additions it has received from the Antarctic surface water as it crosses the ocean.

Between 80 and 200 m. the changes are slightly greater, starting from about the same values just north of the Antarctic convergence.

The very small changes in the temperature and salinity at the level of minimum salinity are shown in Table XI (p. 223). Between 47° S and the sub-tropical convergence there is only an increase of about 0·04 °/₀₀ in salinity and about 0·5° C. in temperature.

At the level of minimum temperature near the bottom of the layer there is a large increase of salinity towards the north as the water mixes with warm deep water, and there is also a small increase in temperature. Between 47 and 38° S there is an increase in salinity from 34·23 to 34·53 °/₀₀ and an increase in temperature from 2·36 to 2·76° C. The increase in temperature is rapid as the Antarctic water sinks below the surface at the convergence; it then becomes slower and is approximately regular between 47 and 38° S.

The way in which the temperature and salinity change with depth has already been described. In the south of the zone the difference in temperature between surface water and that at the bottom of the layer is about 3° C. and near the sub-tropical convergence about 12° C.

To measure the seasonal changes in the temperature and salinity of sub-Antarctic water five stations have been used, WS 69, 138, 252, 318, and 432, which are fairly close together in a position about 100 miles from the Antarctic convergence in approximately 52° 30′ S, 52° 30′ W. The results obtained from so few observations are necessarily only approximate, but they are sufficient to show the nature of the changes which take place.

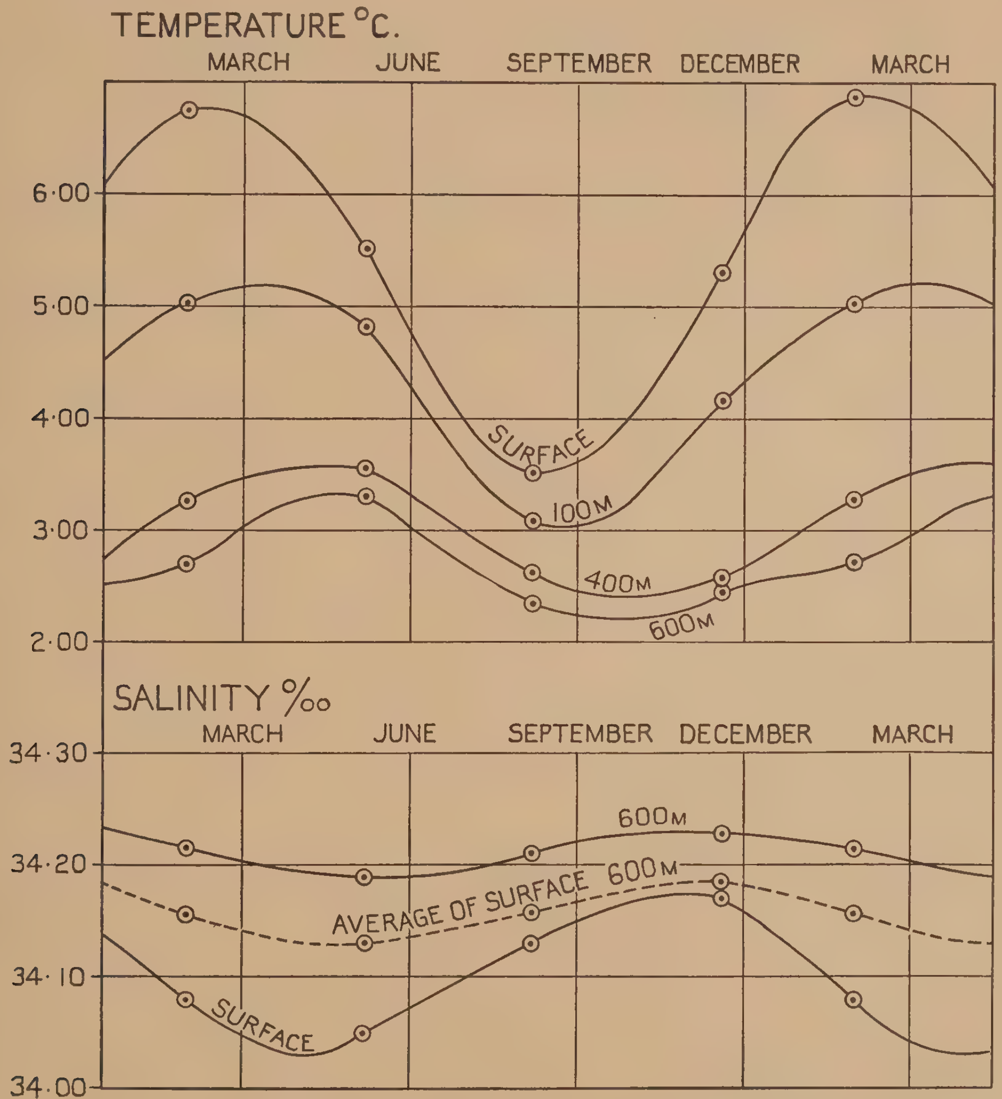

Fig. 21. The seasonal changes of the temperature and salinity of sub-Antarctic water in 52½° S, 52½° W.

The four curves in the upper part of Fig. 21 show the change in temperature from month to month of the water at the surface and at depths of 100, 400, and 600 m. They show that the annual range of surface temperature, at a station about 100 miles north of the convergence, is about 3·4° C.: from 3·5° C. in September to 6·9° C. at the end of February. In the deeper layers the annual range decreases, until at 600 m. it is about

1° C. This is, however, a large seasonal variation of temperature for water at so great a depth, and it is a result of the seasonal variation in the temperature of the Antarctic surface water which sinks to that depth. The maximum temperature at a depth of 600 m. is only reached about two months after the maximum temperature at the surface. This is because the Antarctic surface water, though it has its maximum temperature at about the same time as sub-Antarctic surface water, takes two months to sink to 600 m.

The temperature curves for the water at depths of 100 and 400 m. show that the water at these depths has a maximum temperature at times intermediate between the times of the surface and 600-m. maxima. The surface water has its minimum temperature at the end of August and the water at 600 m. about two months afterwards.

The curves in the lower half of the diagram show the changes in salinity of the water at the surface and at a depth of 600 m., and the dotted line shows the seasonal change in the average salinity of the whole water column from the surface down to 600 m. The annual range at the surface is about 0·14 °/₀₀ and about 0·04 °/₀₀ at a depth of 600 m. At 600 m. the salinity is at a minimum when the temperature is at its maximum, which is what happens in the Antarctic surface water itself. At the surface, however, the minimum salinity is only reached about two months after the maximum temperature, and it appears that the minimum salinity is due to the mixing of Antarctic surface water from below.

The diagram also shows that the difference in temperature between the water at the surface and that at a depth of 600 m. is least in September, when the layer is almost completely mixed, and greatest in February, when, especially in the surface 200 m., there are fairly stable strata in the layer. The line showing the variation in the average salinity of the upper 600 m. of water shows that the layer as a whole, or at least that part of it in the region of intense mixing (which extends to about 100 miles north of the convergence) has its minimum salinity at the end of April and its maximum salinity in November. The curve is not quite symmetrical: the time taken for the water to be reduced from its greatest to its least salinity is about 5½ months, whilst that taken to regain its maximum salinity is about 6½ months. This would be expected if the speeding up of the currents of Antarctic surface water in spring is quicker than the slowing down of the same currents in the autumn.

The nature of these seasonal changes helps to show that sub-Antarctic water has its origin principally in the Antarctic water. The changes, except in surface temperature, lag behind those of Antarctic water and the layer is less directly affected by Antarctic weather conditions.

The distribution of temperature at the surface of the sub-Antarctic Zone is shown in Figs. 8 and 12 (pp. 183, 196). The surface water north of the 3° C. isotherm in the west, and north of 3·5° C. in the east is sub-Antarctic. The isotherms follow the direction of the surface currents. They run approximately south-west to north-east through the Drake Passage and then turn towards the north. Part of the surface water flows between the Falkland Islands and the Patagonian coast, but since the greatest depth in this channel is less than 250 m. the movement is almost confined to the surface stratum. This water together with some which flows northwards to the east of the Falkland Islands forms the Falkland current. The remainder turns eastwards and flows across the Atlantic Ocean. The high surface temperatures north-east of the Falkland Islands are the effect of sub-tropical water, originating in the Brazil current, which has crossed the sub-tropical convergence at the surface and mixed with sub-Antarctic water.

Fig. 13 (p. 197) shows the salinity of the surface 100 m. of water in the Falkland Sector. It shows how great is the effect of the coastal water which flows southwards down the west coast of South America and round Cape Horn, on the salinity of the sub-Antarctic water as far east as the Falkland Islands. When this survey was made the surface salinity south of Cape Horn increased from about 33·30 °/₀₀ or less close inshore, to 34·20 °/₀₀ about 150 miles offshore. Between the Patagonian coast and the Falkland Islands it increased from 33·28 to 33·7 °/₀₀, and then to 34·20 about 150 miles east of the Falkland Islands. The temperature of the sub-Antarctic water affected by the coastal water is about 0·5 to 1° C. higher than that outside its influence.

OXYGEN CONTENT OF THE SUB-ANTARCTIC WATER

Fig. 18 (p. 204) shows that at the end of winter in the south of the sub-Antarctic Zone in 80° W the surface water is about 90 per cent saturated with oxygen; at the level of minimum salinity it is 80 per cent saturated. In 30° W the observations were made at the end of April. The water was about 95 per cent saturated with oxygen at the surface, 90 per cent at a depth of 100 m. and still about 80 per cent in the region of minimum salinity. There are not enough observations to tell how the oxygen content at one particular place varies from season to season; but an examination of the Antarctic intermediate layer, which has its origin in the region of intense mixing north of the Antarctic convergence, shows that the water in this region has its maximum oxygen content at about the same time as its minimum salinity. This indicates that the oxygen content of the layer is renewed by oxygen carried down by the Antarctic surface water. The distribution of oxygen in the sub-Antarctic surface layer is shown in Plate X, which gives the distribution along 30° W expressed in cc. of oxygen per litre of sea water. In the northern half of the zone just south of 40° S the oxygen content decreases below the surface stratum to a secondary minimum between 80 and 100 m. Below this stratum there is a small increase in oxygen content because the oxygen is renewed by water from the region of intense mixing. The oxygen content then decreases with depth; but owing to the sinking of the Antarctic surface water, and the water from the region of intense mixing, the water of the sub-Antarctic layer has a high oxygen content compared with the rest of the water in the South Atlantic Ocean at the same level.

PHOSPHATE AND NITRATE CONTENT OF THE SUB-ANTARCTIC WATER

Measurements made along 30° W show that the phosphate content of sub-Antarctic water is about 80 mg. $P_2O_5/m.^3$ just north of the Antarctic convergence and about 60 mg. $P_2O_5/m.^3$ just south of the sub-tropical convergence. Plate IX shows the vertical distribution of phosphate content along 30° W expressed as mg. $P_2O_5/m.^3$ It will be seen that the water of greatest phosphate content in the South Atlantic Ocean is found in the bottom of the sub-Antarctic layer and in the top of the warm deep layer. Above this greatest content the rest of the layer has also a very high phosphate content, and so great is the ease with which vertical mixing can take place in the upper strata of the layer, that the surface is never depleted of its phosphate. The lowest content measured has been 50 mg. $P_2O_5/m.^3$; this was found in sub-Antarctic water south of the Agulhas current, which contained sub-tropical water mixed with it. Close inshore near Cape Horn at the end of summer the surface phosphate content was 70 mg. $P_2O_5/m.^3$

Measurements of nitrate in sub-Antarctic water are rather few, but those made in the southern half of the zone show that in 30° W the nitrate content of the water at the end of summer was 210 mg. nitrate $N_2/m.^3$; on the eastern side of the South Atlantic a little farther south it was 220 mg. nitrate $N_2/m.^3$ There are no measurements in sub-Antarctic water farther north, but from the vertical distribution of nitrate on the western side of the ocean, which is shown in Plate IX, it appears that the surface content in the northern half of the zone in summer will be about 150 mg. nitrate $N_2/m.^3$

SUB-TROPICAL AND TROPICAL WATERS

SUB-TROPICAL SURFACE AND UNDER-LAYERS, AND THE TROPICAL SURFACE LAYER

In the sub-tropical Zone the surface water is much warmer and more saline than sub-Antarctic water. Just north of the sub-tropical convergence the surface temperature varies from about 15·5° C. in winter to 18·5° C. in summer. The water between the surface and 50 to 60 m. is well mixed; its temperature only decreases 1° C. or less with depth, and its salinity does not alter appreciably with depth. The complete mixing of the surface stratum is brought about by the turbulent movement of pure wind drift currents, and also probably by convection currents resulting from periodical changes in the temperature and salinity of the surface water, which are themselves due to differences in radiation, conduction, and evaporation.

Below the surface stratum the salinity of the sub-tropical water increases slightly, and it is greatest in a stratum between 80 and 100 m. There is probably a component of movement southwards in this stratum, and where the whole layer of water moves southwards the movement will be greatest in this stratum. In 30° W, where the observations on the layer were made, the wind south of 30° S blows principally from the west. It is much weaker than the wind in the sub-Antarctic Zone, but it will give rise to a transport northwards in the surface and a return current at a depth of 80–100 m.

Below the stratum at 80 to 100 m. both temperature and salinity decrease with depth until a sharp discontinuity marks the boundary between sub-tropical water and the sub-Antarctic water which has sunk below the surface south of the sub-tropical convergence. This water is now known as Antarctic intermediate water, because of its intermediate position between surface and deep layers of sub-tropical origin.

The temperature of sub-tropical water in 30° W increases gradually towards the north until, in about 28° S (when the temperature at the surface is 23° C.), the increase becomes rapid, and another surface layer of water can be distinguished.

This second layer lies above sub-tropical water, and is separated from it by another discontinuity of temperature and salinity, forming so sharp a density gradient that vertical mixing between the two layers is almost entirely prevented. The surface layer has been called tropical water. It is almost depleted of its dissolved phosphate and nitrate; and they cannot be renewed, except perhaps very slowly, because the sharpness of the discontinuity makes vertical mixing across it almost impossible. The mean temperature in the discontinuity between the tropical water and the sub-tropical water is 23° C., and the depth of this isotherm has been assumed to be the bottom of the tropical water.

The sub-tropical water which lies below tropical water has been called sub-tropical under-water, and the layer the sub-tropical under-layer, to distinguish it from sub-tropical surface water and the sub-tropical surface layer. The name sub-tropical under-water has already been used by Wüst (1928, p. 514) for water with approximately the same limits of temperature and salinity. The mean temperature in the lower discontinuity which separates sub-tropical surface and under-waters from Antarctic intermediate water is about 10·5° C., and the mean salinity 34·85 to 35·0 °/₀₀. The depth of this temperature and salinity has been assumed to be the depth of the sub-tropical waters. Its depth along 30° W is shown in the following table.

Table V

Latitude	38° S	35° S	30° S	25° S	20° S	15° S	10° S	5° S	0°
Depth of sub-tropical waters in metres	320	440	510	490	440	360	260	290	350

The slope of the discontinuity in a north and south direction, follows approximately the slope of the isobaric surfaces and from it the direction of movement of the water in the sub-tropical layer can be obtained.

Between 38 and 30° S sub-tropical water moves eastwards under the influence of the westerly winds, and the discontinuity slopes downwards towards the north. The easterly movement carries water across the Atlantic Ocean from the Brazil current towards Africa. Some of this water flows south of the Cape of Good Hope, joins water which is turned back from the Agulhas current and flows eastwards across the Indian Ocean. The remainder turns northwards, joins the Benguela current and flows north and east along the west coast of Africa.

Between 30 and 10° S sub-tropical water flows westwards, and the discontinuity slopes upwards towards the north. This westerly movement is the result of the south-east trade winds; it carries water from the Benguela current back to the Brazil current.

The two movements of sub-tropical water complete an anticyclonic water movement which extends over the whole width of the ocean. In the centre of this movement, there is a tendency for the surface water to accumulate and to sink downwards owing to the effect of the earth's rotation on the currents. The sub-tropical water is therefore deepest in the centre of the movement, and in 30° S and 30° W its depth is about 500 m.

Between 10° S and the Equator sub-tropical water flows eastwards; probably as a counter-current below the westward flowing tropical water of the south equatorial current. North of 28° S in 30° W the sub-tropical water is covered by tropical water.

The following table shows the depth of the 23° C. isotherm which has been assumed to show the depth of the tropical water.

Table VI

Latitude	25° S	20° S	15° S	10° S	5° S	0°
Depth of tropical water in metres	70	130	145	115	80	70

North of 18° S tropical water flows westwards in the south equatorial current and as it approaches the Brazilian coast this current is partly deflected southwards into the Brazil current. As it flows southwards, the Brazil current loses water from its left-hand side in a surface drift towards the east, and in 30° W the tropical water south of 18° S is moving eastwards. The tropical water is deepest in 18° S, in the centre of the anticyclonic movement between the south equatorial current and this movement towards the east. These movements are shown on the chart of surface currents in the Atlantic Ocean by Meyer (1923).

TEMPERATURE AND SALINITY OF THE SUB-TROPICAL AND TROPICAL WATERS

The surface temperature of sub-tropical water increases towards the north from about 15·5° C. in winter or 18·5° C. in summer near the sub-tropical convergence; it increases to 23° C. before it becomes covered with the tropical surface layer. Its surface salinity increases from about 35·0 to 36·0 °/$_{oo}$ over the same distance. In the bottom of the layer the salinity increases from 34·85 to 35·00 °/$_{oo}$ and the temperature remains about 10·5° C.

From the surface to 50–60 m. sub-tropical water is almost uniform. Below it there is a stratum of slightly higher salinity, and below this again the temperature and salinity decrease gradually with depth until the discontinuity which forms the boundary of the Antarctic intermediate layer is reached.

The surface temperature of tropical water increases from 23° C. in 28° S to a maximum of 28–29° C. just north of the Equator. Between the surface and the discontinuity which separates the layer from the sub-tropical under-layer the temperature of tropical water varies very little with depth.

The salinity of the tropical surface layer increases from about 36 °/$_{oo}$ in 28° S to a maximum of 37·4 °/$_{oo}$ in about 18° S. It then decreases towards the north in the south equatorial current. In 9° 47′ S the salinity remained uniform with depth down to 50 m., and then increased to a maximum at 100 m. This is probably because the transport of surface water, which under the influence of the east winds was towards the south, must be compensated by a movement northwards between 80 and 100 m., similar to that which has been found to move southwards in the region of westerly winds. The lowest salinity found in the surface stratum was about 35·9 °/$_{oo}$ just north of the Equator. The salinity of tropical water in the discontinuity separating it from the sub-tropical under-water also varies from about 35·8 to 37·0 °/₀₀. It is greatest between 20 and 10° S, and least just north of the Equator.

OXYGEN CONTENT OF THE SUB-TROPICAL AND TROPICAL WATERS

The oxygen content of the sub-tropical water is approximately 95 per cent of saturation, and the oxygen content between the surface and 50–60 m. (which must be in constant circulation) is almost uniform with depth. There is, however, always a small maximum at a depth of 60 m., which must be caused by the maximum growth of diatoms at that level. The oxygen content in the bottom of the layer decreases from about 80 per cent in 40° S, to 75 per cent in 28° S.

The surface of tropical water is about 96 per cent saturated with oxygen between 28 and 20° S, but then the oxygen content decreases slightly to a minimum of about 93 per cent between 15 and 10° S in the south equatorial current. The oxygen content of tropical water increases with depth and is at a maximum just above the discontinuity which separates the layer from the sub-tropical under-layer. This maximum is again probably due to the greater growth of diatoms at that depth, the diatoms utilizing the small amounts of phosphate and nitrate liberated in tropical water as a result of the slight vertical mixing which takes place across the discontinuity.

The oxygen content of the sub-tropical under-layer can only be replenished by a horizontal inflow of water, since the layer is shut off from the surface by a discontinuity which does not allow vertical mixing. The oxygen content of the layer falls from about 80 per cent of saturation in 28° S to about 40 per cent at the Equator.

PHOSPHATE AND NITRATE CONTENT OF THE SUB-TROPICAL AND TROPICAL WATERS

In 30° W the phosphate content of the surface stratum falls at once from about 60 mg. P_2O_5/m.^{3} to 10 mg. on passing from sub-Antarctic to sub-tropical water. The nitrate content also decreases from about 150 mg. nitrate N_2/m.^{3} to 50 mg., and a little farther north to 10 mg. Both decrease towards the north until just south of 28° S, the phosphate content of the surface stratum is 8 mg. P_2O_5/m.^{3}, and the nitrate content is 5–6 mg. nitrate N_2/m.^{3}

In the surface stratum of tropical water there is no phosphate and it must be completely used up as soon as it is regenerated. There is usually a small nitrate content of 0–5 mg. nitrate N_2/m.^{3}, and this is replenished from rain water, which has been found to contain as much as 10 mg. nitrate N_2/m.^{3} after a thunderstorm. The nitrate is probably not used up because of the absence of phosphate.

In sub-tropical water the phosphate and nitrate contents increase with depth until there is about 35 mg. P_2O_5/m.^{3} and 150 mg. nitrate N_2/m.^{3} in the discontinuity level.

The sub-tropical Zone is not very favourable for diatom growth in general because of the small amounts of phosphate and nitrate at the surface. It is not, however, entirely depleted of them, and where they are replenished by upwelling, such as takes place off the African coast, the conditions are very good. The tropical water can only support such growth as can exist on the small amounts of phosphate which are obtained from the sub-tropical under-layer.

EXTENT OF THE SUB-TROPICAL AND TROPICAL ZONES

The tropical convergence, between tropical and sub-tropical waters, is not so well defined as the other convergences. It is found at the surface where the increase in surface temperature from south to north becomes more rapid, and where the surface stratum becomes shut off from sub-tropical water by a sharp discontinuity. In the South Atlantic Ocean it corresponds in summer with the 23° C. isotherm.

The tropical Zone extends to about 28° S in the western half of the ocean where the Brazil current carries tropical water southwards, but only to 10–15° S in the east where the Benguela current carries sub-tropical water northwards. The boundary between it and the sub-tropical Zone lies between St Helena and Ascension. Hydrologically St Helena is sub-tropical, and Ascension tropical. The water off the Cape of Good Hope, and off the west coast of Africa as far as 10–15° S, is sub-tropical; but close inshore, particularly south of 20° S, it is also influenced by upwelling water from the Antarctic intermediate layer.

THE DEEP WATERS OF THE SOUTH ATLANTIC OCEAN

There are three principal deep layers in the South Atlantic Ocean. They are: the Antarctic intermediate layer, the warm deep layer, the Antarctic bottom layer.

It has already been shown that the Antarctic surface water which sinks at the Antarctic convergence mixes with sub-Antarctic water in a region of intense vertical mixing just north of the Antarctic convergence. The mixture of water then sinks downwards towards the north, and spreads over the whole of the South Atlantic Ocean. It gives rise to a layer of water which is both Antarctic and sub-Antarctic in origin, and it is found farther north between layers of sub-tropical water, and warm deep water, both of which are of sub-tropical origin. The layer has therefore been called the Antarctic intermediate layer, and the water Antarctic intermediate water.

Below the Antarctic surface water in the Antarctic Zone, below the sub-Antarctic water in the sub-Antarctic Zone, and below the Antarctic intermediate layer farther north there is a layer of water which has been called the warm deep layer. It is most probable that all the water in the warm deep layer is not of the same origin. Brennecke (1921) and Wüst (1928) have shown that a stream of North Atlantic deep water flows southwards in the South Atlantic from its origin in the sub-tropical regions of the North Atlantic. Clowes (1933) has shown that south of 46° S the water in the layer is derived from the Pacific Ocean. In the Antarctic Zone the maximum temperature in a vertical column of water is found in the warm deep layer, but north of the Antarctic convergence there is only a secondary temperature maximum in the layer because there are warmer layers of water nearer the surface.

Below the warm deep layer there is a heavy type of Antarctic water which has been formed by the cooling of warm deep water without appreciable dilution. It sinks near the Antarctic Continent to fill the deep polar basins and then flows northwards along the sea bottom. It has been called Antarctic bottom water.

ANTARCTIC INTERMEDIATE WATER

STRUCTURE AND DEPTH OF THE ANTARCTIC INTERMEDIATE LAYER, AND THE ORIGIN AND MOVEMENTS OF ANTARCTIC INTERMEDIATE WATER

The Antarctic intermediate layer is distinguished in any vertical series of observations made in the sub-tropical or tropical Zones, by its low salinity. Below the sub-tropical water the salinity decreases until it reaches a minimum value, and then it increases. The water on either side of the level of minimum salinity is Antarctic intermediate water. It has its origin in the region of intense mixing just north of the Antarctic convergence. The path of the water forming the layer can easily be followed in Plate VIII which shows the vertical distribution of salinity along the meridian of 30° W.

In the Antarctic intermediate layer three strata may be distinguished. (i) At the bottom of the layer, where the temperature is lowest, there are the last traces of Antarctic surface water, which have sunk from the cold stratum of the Antarctic surface layer. (ii) At the level of minimum salinity the water has its origin in the mixture of lighter Antarctic surface water and sub-Antarctic water which is formed just north of the Antarctic convergence. (iii) Above the level of minimum salinity there is water which has sunk below the surface in the sub-Antarctic Zone, but north of the region of intense mixing, and is less Antarctic, or more sub-Antarctic, in origin. The greater part of the layer is, however, composed of the water of low salinity which has its origin in the region of mixing just north of the Antarctic convergence.

The following table shows the depth of the water of minimum salinity in different latitudes in 30° W.

Table VII

Latitude	45° S	40° S	35° S	30° S	25° S	20° S	15° S	10° S	5° S	0°	5° N	10° N	15° N
Depth of minimum salinity in metres	380	630	900	940	900	830	700	740	700	700	770	800	800

These depths show the path of the water of minimum salinity which forms the nucleus of the layer as it flows northwards.

The temperature in the layer decreases until it reaches a minimum value near the bottom of the layer. This level of minimum temperature can be followed as far back as the Antarctic Zone and it is continuous with the level of minimum temperature in the cold stratum of the Antarctic surface layer. The depth of the level of minimum temperature is given in the following table for latitudes from 57° 30′ S to 5° S in 30° W.

Table VIII

Latitude	57° 30′ S	55° S	50° S	45° S	40° S	35° S	30° S	25° S	20° S	15° S	10° S	5° S
Depth of minimum temperature in metres	80	80	125	900	1200	1660	1700	1400	1300	1060	1050	1000

Below the level of minimum temperature, the temperature increases to a maximum value in the upper stratum of the warm deep layer, and the water in this stratum, whatever its origin may be, has a component of movement southwards. Table IX shows the depth of this maximum temperature in 30° W, together with the depth of the maximum salinity in the warm deep layer.

Table IX

Latitude	57° 30′ S	55° S	50° S	45° S	40° S	35° S
Depth of maximum temperature of warm deep water in metres	600	600	600	1300	1800	2260
Depth of the maximum salinity of the warm deep layer in metres	700	640	1650	2300	2950	—

Latitude	30° S	25° S	20° S	15° S	10° S	5° S
Depth of maximum temperature of warm deep water in metres	2260	2080	1800	1480	1450	1300
Depth of the maximum salinity of the warm deep layer in metres	3400	2800	2650	2000	2000	2000

The boundary between sub-Antarctic or Antarctic intermediate water and the warmer layer beneath—that is to say the boundary between the north- and south-going movements—may be regarded with sufficient accuracy as lying midway between the levels of minimum and maximum temperatures.

The following table shows the depth of this boundary in 30° W.

Table X

Latitude	45° S	40° S	35° S	30° S	25° S	20° S	15° S	10° S	5° S
Depth of the boundary between sub-Antarctic or Antarctic intermediate water, and warm deep water in metres	1100	1500	1960	1980	1740	1550	1270	1250	1150

The origin of the water in the Antarctic intermediate layer has been discussed by Brennecke (1921, p. 140), who describes the movement in the layer as the sub-Antarctic deep current; he gives its origin as the surface drift out of the Weddell Sea, which sinks in about 50° S and pushes its way, at an average level of about 1000 m., through the South Atlantic Ocean as far as 25° N. The layer is also described by Drygalski (1927, p. 498) who describes its origin as Antarctic polar water. Both descriptions are correct although not complete.

TEMPERATURE, SALINITY AND OXYGEN CONTENT OF ANTARCTIC INTERMEDIATE WATER

Although it has probable movements from west to east and east to west, the Antarctic intermediate water flows northwards. This is proved by the fact that the layer which extends as far north as 25° N in the West Atlantic contains water which can only have had its origin south of 40° S. As the water flows northwards its properties change as a result of the vertical mixing which takes place between the water in the layer and the waters above and below it. The changes are greatest at the top and bottom of the layer where the effect of vertical mixing is greatest, and least at the level of minimum salinity which forms the nucleus of the layer.

It is difficult to trace the changes in the upper stratum of the layer, since the path of the water is not indicated by any maximum or minimum in temperature or salinity which can be followed. The water which has a temperature of more than 10·5° C. has been considered to be sub-tropical, and the origin of much of the water in the sub-tropical layer must be in Antarctic intermediate water, which has been warmed, and had its salinity increased, by mixing across the discontinuity.

In the bottom of the Antarctic intermediate layer, at the level of minimum temperature, the changes can be followed more easily. The temperature at this level increases from 2·78° C. in 34° 08′ S to 4·12° C. in 03° 19′ S, and the salinity from 34·62 °/oo in 34° 08′ S to a maximum of 34·73 °/oo in about 18° S. The increase in temperature is the result of mixing with the warmer waters which lie both above and below it. The increase in salinity is the result of mixing with the more saline water below and the less saline water above. North of 18° S the salinity in the level of minimum temperature decreases from 34·73 to 34·59 °/oo in 03° 19′ S, because there is an increasing percentage of Antarctic intermediate water in the mixture at this level.

The changes of temperature and salinity at the level of minimum salinity, where the layer is least changed by vertical mixing, are most interesting. They are shown, together with the figures for oxygen content, in the following table.

Table XI

Latitude	Depth of minimum salinity m.	Minimum salinity °/oo	At depth of minimum salinity	
			Temperature ° C.	Oxygen content c.c./litre
South				
46° 43′	330	34·15	3·23	6·02
43° 08′	410	34·16	3·52	5·94
38° 17′	800	34·22*	3·86	5·45
34° 08′	910	34·26	3·96	5·19
31° 16′	940	34·28	4·00	4·86
26° 07′	910	34·33	4·00	4·59
21° 13′	850	34·38	4·11	4·24
15° 37′	700	34·41	4·56	4·08
09° 47′	750	34·49	4·40	3·50
03° 19′	690	34·50	4·68	3·36
North				
02° 59′	740	34·51	5·02	3·06
08° 54′	800	34·69	5·86	2·18
14° 27′	800	34·83	6·41	2·37

* This value obtained graphically.

It will be seen from this table that the temperature and salinity both increase towards the north as a result of vertical mixing. The increase is approximately proportional to the distance the water travels; but it is not regular, and there are patches of warmer and less saline water alternating with patches of cooler and more saline water. The oxygen content of the water decreases towards the north as the oxygen is used up by animal life and by oxidizable organic matter in the water. The decrease in oxygen content is also approximately proportional to the distance the water flows, and it is not regular. There are alternate patches of water with high oxygen content and low oxygen content.

The irregularity in the increase in temperature and salinity, and in the decrease in oxygen content, is partly due to the difference between the water which leaves the region of intense mixing just north of the Antarctic convergence in winter, and that which leaves in summer. The mixture of waters in this region has its maximum temperature and minimum salinity at the end of the summer. Both are the result of the higher temperature and lower salinity of the Antarctic surface water which sinks in summer, and it is to be expected that the mixture will have its maximum oxygen content at about the same time. This will be so because the Antarctic surface water has its greatest oxygen content in spring and early summer, when the phytoplankton is at its maximum, and also because there is probably a greater percentage of Antarctic surface water in the mixture in summer than there is in winter when the surface currents are slower.

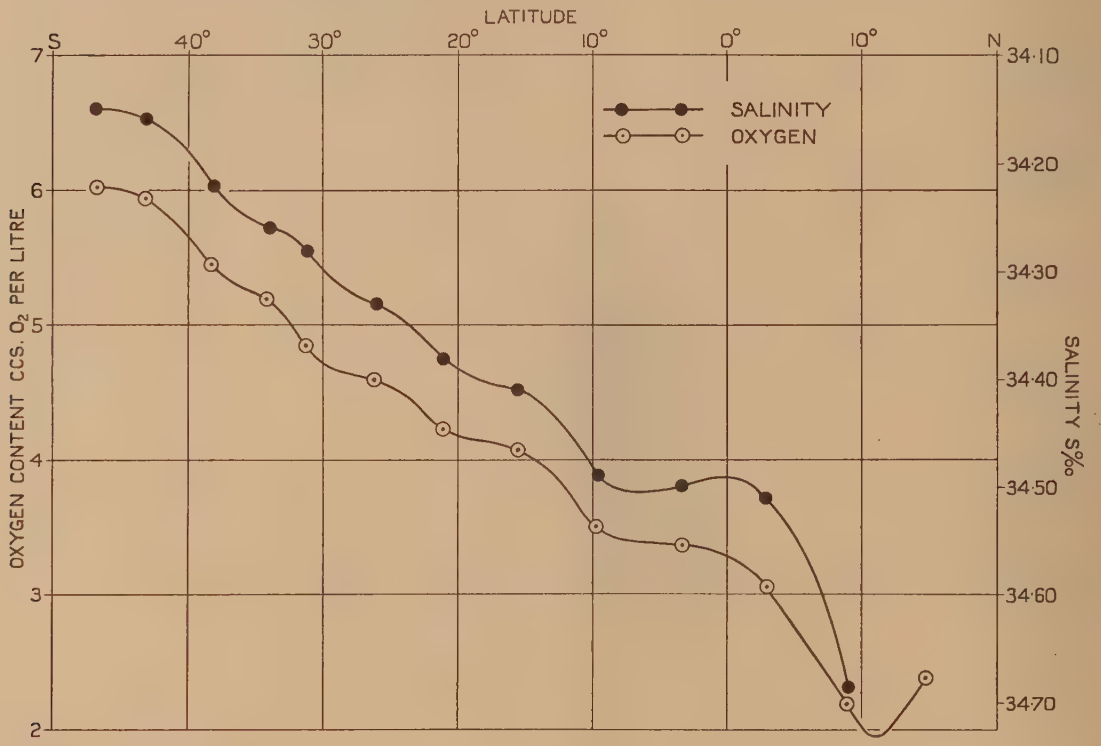

Fig. 22. The change in the salinity and oxygen content towards the north in the Antarctic intermediate current.

Fig. 22 shows the oxygen content and salinity of the water at the level of minimum salinity in different latitudes in 30° W. To make comparison of the curves easier the salinity scale has been made to read in a negative direction, the downward slope of the curves towards the north thus showing a decrease in oxygen content, but an increase in salinity.

The two curves, which are approximately parallel, show maxima and minima which correspond to the water which flows northwards from the region of mixing in different seasons. Water which sinks from the Antarctic surface layer and flows northwards in summer has a greater oxygen content and a lower salinity than water which sinks and flows northwards in winter. There are not sufficient points on the curves to allow them to be drawn exactly, but if they have any meaning at all their shape cannot differ very much from that shown. From the distance apart of the consecutive maxima or minima the distance travelled by the water in one year can be calculated.

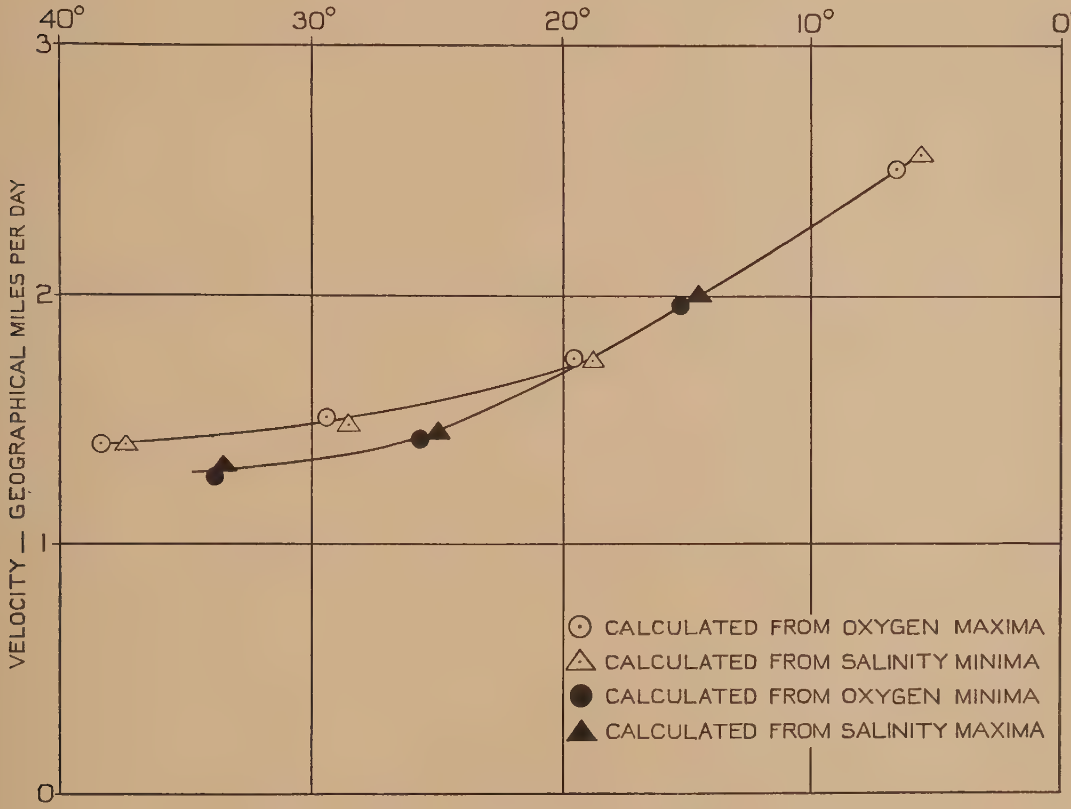

Fig. 23. The change in the speed of the Antarctic intermediate current towards the north.

In Fig. 23 the velocities calculated in this way have been plotted against latitude. South of 20° S the velocities calculated from consecutive oxygen maxima and salinity minima are greater than those calculated from the oxygen minima and salinity maxima. This difference would arise if the water which sinks in winter flows, at first, more quickly than that which sinks in summer, and this might be the result of the greater density of Antarctic surface water in winter, causing it to sink more quickly and take a more direct path northwards. The difference could also be explained if the water of minimum salinity and maximum oxygen content were the first to increase its speed in the general increase in velocity towards the north.

At the depth of minimum salinity the average velocity of the water in the layer increases from about 1·3 miles a day in 40° S to 2·5 miles a day in 7° S. The increase in velocity may be caused by the narrowing of the South Atlantic Ocean towards the north, as well as to the decreasing thickness of the layer, which becomes more confined between sub-tropical water and North Atlantic deep water.

In addition to this movement towards the north, there are easterly and westerly movements in the layer; but about these little is known. The layer is deepest in about 30° S between the region of west and east winds. South of 30° S there will probably be a movement in the layer towards the east, which is partly responsible for the slope of the isotherms and isohalines downwards towards the north, and north of 30° S a weaker movement towards the west. These zonal movements will affect the curves in Fig. 22, but not enough to destroy them.

The velocity of the Antarctic intermediate current towards the north has recently been measured on the eastern side of the South Atlantic, and similar results have been obtained to those already described. A preliminary account of the measurement of these velocities (Deacon, 1931) has also been confirmed by Castens (1931), who obtained a similar result from the changes in temperature with latitude. The movement northwards can be considered as a series of waves of water of different properties moving outwards from the Antarctic regions, each of which, in the Atlantic Ocean, takes about 4½ years to travel from the Antarctic convergence to the Equator.

The salinity of the water at the level of minimum salinity only increases from 34·15 to 34·56 °/₀₀ between 47° S and the Equator. The temperature increases from 3·2 to 4·85° C. over the same distance, and the oxygen content decreases from 6·0 to 3·3 cc./litre. North of the Equator the increase of temperature and salinity is more rapid, and the most northerly observations which show the minimum salinity typical of the layer are those of the 'Planet' (1909) in 24° 20′ N, 22° 37′ W, and the 'Möwe' (1914) in 26° 10′ N, 16° 42′ W. Antarctic intermediate water will reach this point about six or seven years after it left the surface in the Antarctic.

THE WARM DEEP WATER

STRUCTURE AND DEPTH OF THE WARM DEEP LAYER, AND THE ORIGIN AND MOVEMENTS OF THE WARM DEEP WATER, THE NORTH ATLANTIC DEEP WATER AND THE PACIFIC DEEP WATER

The movement of Antarctic surface water away from the Antarctic regions towards the north is known to take place all round the pole, and it is also known that there is a similar movement of Antarctic bottom water towards the north near the sea-bottom. To make up for this transport of water away from the Antarctic regions in the surface and bottom layers there must be a movement towards the pole in the intermediate layer. This is supplied by a movement southwards in the warm deep layer.

In any series of vertical observations made inside the Antarctic Zone it will be seen that the temperature either remains constant or decreases with depth down to the level of the cold stratum of the Antarctic surface layer. Below this level it increases to a maximum in the warm deep water, and then it decreases again, down to the sea-bottom. If there were no current southwards in the warm deep layer, the maximum temperature of the warm deep water would soon disappear as a result of vertical mixing between the water in the layer and the colder waters above and below it.

There can be no doubt then that the water at the level of maximum temperature in the Antarctic Zone has a component of movement southwards. The way in which the warm deep layer feeds the surface layer has already been described in the first section of this report, and it will be shown later that it also gives rise to Antarctic bottom water. The origin of the warm deep water in the Antarctic Zone can best be decided from sections which show the vertical distribution of temperature and salinity.

In both the sections shown on Plate VIII it appears that the water in the warm deep layer south of 50° S has its origin in the North Atlantic deep current, which climbs rapidly towards the surface at the Antarctic convergence. It must, however, be remembered that the deep currents may have zonal as well as meridional movements: a deep current from the Pacific Ocean, in which the water is very similar to that in the North Atlantic deep current, will not be distinguished in the sections. None the less the sections show that the warm deep layer in the Antarctic Zone is continuous with the warm deep layer below the sub-Antarctic and Antarctic intermediate waters, even although the warm deep water in the continuous layer is not all of the same origin.

Clowes (1933) has shown that the warm deep water south of 46° S in 30° W has its origin in the Pacific Ocean. Further work shows that most of the Pacific deep water is probably stopped at the Scotia Arc, and also that in 40° S between the observations in 30° W and those of the 'Deutschland' in 50° W, there is a strong movement of North Atlantic deep water southwards. The conclusion that the water south of 46° S had its origin in the Pacific Ocean was based partly on the differences of salinity and temperature at St. 666 and 671. These differences are alternatively explained by the slope of the warm deep layer and the greater reduction of the layer at St. 666 by vertical mixing.

So great is the similarity between North Atlantic and Pacific deep water that there is as yet no very reliable evidence to show the origin of the warm deep water just north of the Scotia Arc. The temperature at its level of maximum salinity is greater than the temperature of the water of maximum salinity in the Pacific Ocean, and at the same time the maximum salinity itself is greater. The water north of the Scotia Arc must therefore contain additions from the Atlantic Ocean. The warm deep water in the Scotia Sea probably has a Pacific origin, but this in my opinion is as yet uncertain.

Fig. 24 shows the temperature of the warm deep layer in the Falkland Sector. It has been constructed by plotting the maximum temperature which has been found in the layer, and not the temperature at any particular depth. The diagram does not necessarily show direction of movement, but there is usually a component of movement from warm to cold regions and not from cold to warm. Regions of low temperature

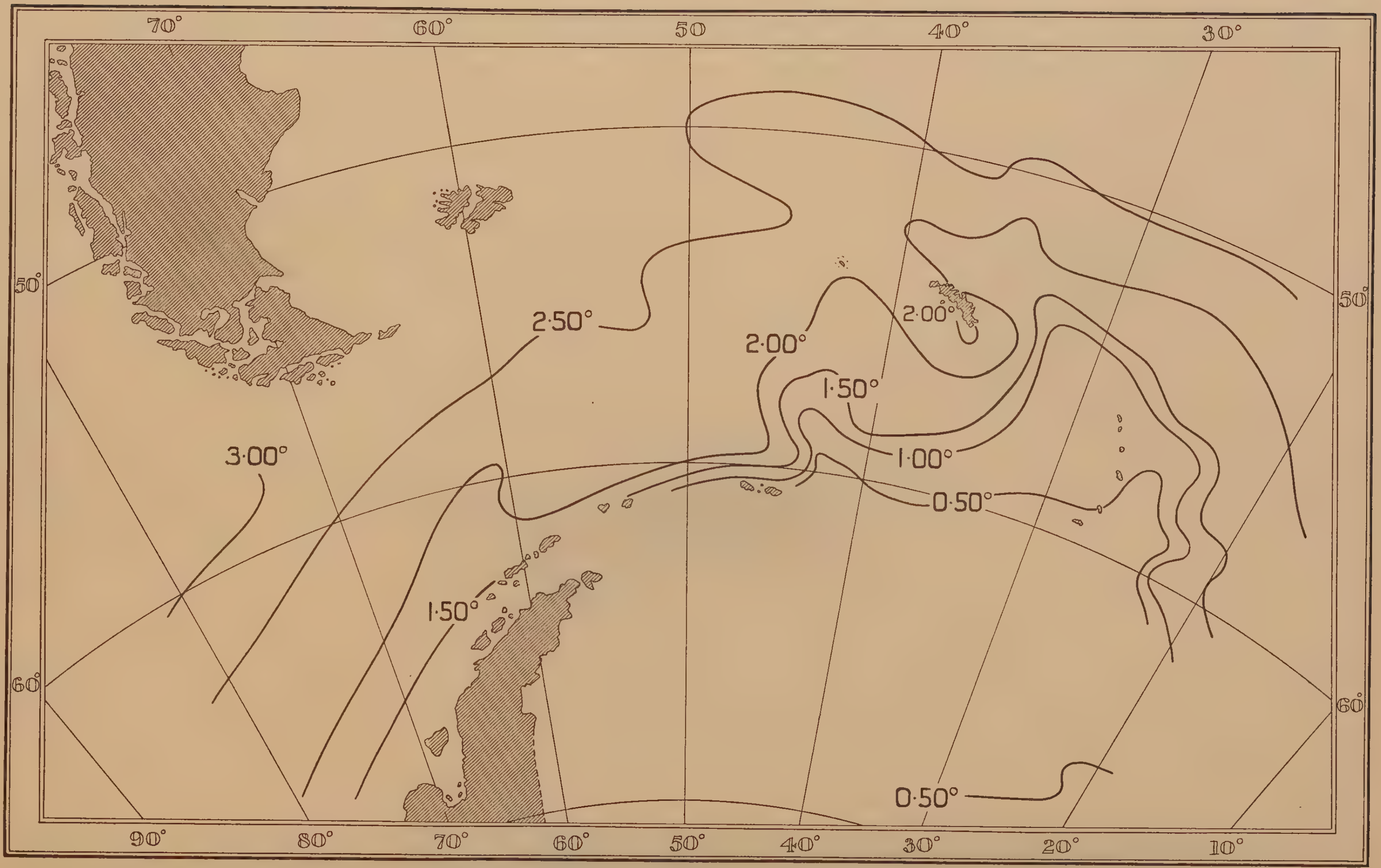
70°
60°
50
40°
30°
50°
60°
2·50°
3·00°
2·00°
2·00°
1·50°
1·00°
0·50°
1·50°
0·50°
90°
80°
70°
60°
50°
40°
30°
20°
10°

Fig. 24. The temperature of the warm deep water in the Falkland Sector (° C.).

are regions where there is greater mixing of the warm deep layer with Antarctic surface and bottom waters.

Although the isotherms do not show the direction of movement of the warm deep water, they show the relative strength of the deep and bottom movements. When the strength of the bottom current towards the north or north-west increases, or when the strength of the warm deep current towards the south-east decreases, the isotherms recede towards the north. When there is a stronger flow of warm deep water, or a lesser flow of cold bottom water they advance towards the south.

In an investigation of the origin of the deep water in the Falkland Sector the problem is complicated by the presence of a cold deep current flowing out of the Weddell Sea. It has been shown by Wüst in 5° E, by Brennecke in 30° W, and by ourselves in 15° E, 15° W and 20° W, that south of about 66° S the temperature in the warm deep layer increases towards the south, and it is now almost certain that north of this warmer deep water there is a continuous belt of colder water stretching from the Weddell Sea to 15° E. East of 15° E, however, warm deep water gets far south without interruption, and the warm deep current in the Atlantic south of 66° S has its origin east of 15° E. It flows westwards as a result of the prevailing easterly winds south of 66° S, and Wüst has pointed out that this is proved by its decrease in temperature towards the west. As it flows round the Weddell Sea in a cyclonic movement similar to that which takes place at the surface the deep current is cooled by vertical mixing.

There is, however, always a warm deep layer in the Weddell Sea (except perhaps very close inshore in the west of the sea): the temperature always increases below the Antarctic surface layer to a maximum in this deep water before it decreases to a minimum value at the bottom. By the time it flows out of the northern side of the sea the deep water has only a maximum temperature of about 0·40° C. or less, and as soon as it meets warm deep waters of Pacific and Atlantic origin it both sinks below them and mixes with them. It is then perhaps best described as a cold deep current.

The cold deep current from the Weddell Sea follows the bottom current. Part of it flows eastwards across the Atlantic Ocean; part of it flows north across the Scotia Sea, or round the outside of the Scotia Arc, and sinks below the warm deep water north of South Georgia. The cold deep current is partly responsible for the sudden climb of the warm deep layer north of South Georgia, and also for the sudden differences in temperature and salinity in deep levels south of 40° S, north of South Georgia. Its effect on the deep temperature distribution in the east of the Scotia Sea and north-east of South Georgia is shown in Fig. 24.

As mentioned above, Brennecke and Wüst have shown that the warm deep water of Atlantic origin is formed in the sub-tropical region of the North Atlantic. It sinks below the surface in the convergence region between the Canary current, the North Equatorial current, and the Gulf Stream. It is also mixed with the last traces of Antarctic intermediate water from the same region, and in the east with water from the Mediterranean Sea (Wüst, 1928, p. 522). As it flows southwards it mixes with Antarctic intermediate water and sub-Antarctic water and picks up from them a large concentration of phosphate and nitrate in its upper stratum.

Not much is known of the origin of Pacific deep water, but when it is in the Atlantic it differs very little in properties from North Atlantic deep water.

The warm deep water which flows westwards in the south of the Weddell Sea, and eventually out of the Weddell Sea as the cold deep current, flows from the Indian Ocean. It cannot yet be definitely stated whether it flows into the Indian Ocean from the Atlantic or whether it has its origin in the north of the Indian Ocean.

TEMPERATURE, SALINITY AND OXYGEN CONTENT OF THE WARM DEEP WATER

The upper stratum of warm deep water is characterized by a secondary temperature maximum and it is warmer than the bottom stratum of Antarctic, sub-Antarctic, and Antarctic intermediate waters. The temperature in the warm deep layer decreases with depth, but its salinity increases with depth until it reaches a maximum at a level which can be considered the nucleus of the layer—just as the minimum salinity level was considered to be the nucleus of the north-going Antarctic intermediate water.

The depth interval between the depths of maximum temperature and maximum salinity in the layer is a measure of the thickness of the layer. The thickness can be obtained from Table IX (p. 222), and it will be seen that it is not uniform. The depth of the level of the maximum salinity, and the thickness of the layer, are greatest in the deep basins and least above the zonal ridges and rises which cross the West Atlantic basin.

The temperature and salinity in the nucleus of the layer decrease towards the south, and their decrease is due to vertical mixing with the Antarctic intermediate and bottom waters. The decrease is not regular, partly because the North Atlantic deep water which supplies the current must vary in just the same way as the water supplying the Antarctic intermediate current. The rate of decrease also shows some dependence on the thickness of the layer, owing to the changing speed of the water, or because of lateral inflow of water in the basins. Attempts to measure the speed of flow of the water are rendered difficult by these changes, which are fortunately not communicated to the layer above.

In 50° S and 30° W the depth between the maximum temperature and maximum salinity of the warm deep water is about 1000 m., but in 55° S it is only 40 m. This is probably because the lower strata of warm deep water, whether their origin is Atlantic or Pacific, have been changed or deflected by the strong flow of Antarctic bottom water, or of cold deep water, from the Weddell Sea towards the Argentine Basin past the north-east coast of South Georgia.

The depth between the maximum temperature and the maximum salinity generally decreases in the direction of movement, or as the temperature itself decreases. The maximum temperatures of the layer in the Falkland Sector have been shown in Fig. 24. The maximum salinity varies from about 34·73 or 34·74 °/₀₀ below the Antarctic convergence to 34·67 °/₀₀ in the cold deep water of the Weddell Sea.

From north to south the temperature at the level of maximum salinity decreases from 3·93° C. in 14° 27′ N to 0·67° C. in 57° 36′ S, and the salinity decreases from 34·97 to 34·68 °/₀₀ over the same distance.

The stream of North Atlantic deep water is most saturated with oxygen north of the Rio Grande ridge, which crosses the West Atlantic basin in about 34° S. It contains most oxygen at a depth of 2000–3000 m., where the water is about 75 per cent saturated and contains from 5 to 5·5 cc. O_2/litre. There is a second stratum of high saturation in the layer between 3000 and 4000 m., and the average saturation of the whole layer is about 70 per cent.

The oxygen content decreases only slowly towards the south until the water has crossed the Rio Grande ridge. Then the decrease is more rapid, and in the upper stratum the oxygen content falls to 3·8 cc./litre and the saturation to 50 per cent. The rapid decrease south of the ridge is probably due to the greater consumption of oxygen by the greater amount of animal life and oxidizable matter in the water. It may also be due to a decrease in the southerly component of the deep-water movement.

The deep water in the Antarctic Zone is thus poorly oxygenated compared with the deep water farther north; it contains most oxygen near the bottom of the layer, where it is enriched by mixing with Antarctic bottom water. The oxygen content of the layer in the Antarctic Zone is shown in Figs. 18 and 19 (p. 204) expressed as a percentage saturation, and in Plate X as cc. O_2/litre.

The seasonal changes in the temperature and salinity of the warm deep water have not yet been worked out, but it has been shown that there are considerable changes whose period is not yet known. There are patches of different temperature and salinity in the North Atlantic deep current as it flows southwards, and the changes in the properties of the deep water at a particular station may be the result of the arrival of these patches at different times.

ANTARCTIC BOTTOM WATER

THE ANTARCTIC BOTTOM LAYER, AND THE ORIGIN AND MOVEMENT OF ANTARCTIC BOTTOM WATER

Below the warm deep layer there is a colder layer of water, which has its origin in the Antarctic regions. In the Antarctic Zone this layer is not separated from the warm deep layer by a discontinuity in the changes of temperature and salinity with depth, and it is difficult to decide upon the level at which the movement of warm deep water southwards changes to one of Antarctic bottom water northwards.

The formation of Antarctic bottom water has been explained in various ways. It is clear from its properties, and the level at which it is found, that it must consist of warm deep water which has been cooled without being appreciably diluted. It could be formed if the warm deep water were exposed for some period at the surface, especially in winter; but such exposure is not known to take place, for the layer is always found to be covered by colder and less saline Antarctic surface water.

Nansen (1912) explains the formation of similar water in the Arctic Ocean as due to a convective circulation which carries water downwards from the surface to the bottom in autumn and early winter. Brennecke (1921, p. 140) says that it is formed along the continental shelf of the Antarctic Continent where the surface water is cooled right through and sinks down the continental slope. Drygalski (1927, pp. 495 *et seq.*) states that the bottom water is a mixture of the cold water formed on the continental shelf with the deep water. Wüst (1928, p. 525) at first followed Nansen's explanation. He thought that when the surface currents became slower in autumn and winter Antarctic bottom water was formed by the sinking of highly saline surface water in the centre of two cyclonic movements, one in the Weddell Sea and one farther east.

The difficulty which prevented acceptance of the explanations of Brennecke and Drygalski was that there was always found to be a continuous warm deep layer, even at stations very far south, through which the cold water formed on the continental shelf did not appear to sink. There are, however, insufficient observations to show that this sinking of water does not take place, particularly in winter along the east coast of Graham Land.

In a more recent publication (1933, p. 48) Wüst has concluded from the distribution of potential temperature (the temperature to which the water would be adiabatically cooled if it were raised to the surface) that Antarctic bottom water in the Atlantic is formed in the way suggested by Brennecke. He has also distinguished a slightly warmer bottom water which he has called Antarctic deep water. He suggests that the two cyclonic water movements distinguished by Meyer (1923) in the Weddell Sea, and in 30° E, do not exist, and that there is instead a convergence region similar to that shown by Willimzik (1927) and Möller (1929) in the Indian Ocean. He considers that the convergence region lies between 60° and 65° S in the Weddell Sea, and between 56° and 60° S farther east. Its position is closely related to that of the northern edge of the pack-ice. Antarctic deep water—according to Wüst—would be water which sinks in this region in autumn and winter.

The existence of a convergence region in the Weddell Sea is however hypothetical; our observations and those of Brennecke seem to show that there is simply a divergence region between the currents flowing west and east. In this divergence region warm deep water and Antarctic bottom water upwell, and tend to flow outwards (to the left) in, or just below, the surface layer. At the edges of the sea, and particularly along the east coast of Graham Land, heavy water will sink downwards. Most water will probably sink in winter when the surface water is coldest and most saline. The water which sinks need not have a salinity as high as the warm deep water because it is colder, and because the sinking is partly due to dynamic forces.

The observations of the 'Deutschland' (Brennecke, 1921) show that the surface water in winter has a salinity of almost 34·50 °/₀₀, and closer inshore it may be much more. By the sinking of this water and its mixture with warm deep water, which in the west of the Weddell Sea has a maximum temperature of 0·40° C. or less, both Antarctic bottom water and Wüst's "Antarctic deep water" can be formed. If they are both formed in this way it is difficult to distinguish between them, and it is perhaps best to describe all the water which spreads northwards below the warm deep water as Antarctic bottom water. If not, in a region such as the Drake Passage, where the bottom water is not so cold as it is in the Weddell Sea, it must be called Antarctic deep water. It is worth while making an exception of the cold deep current flowing out of the Weddell Sea, because it can still be clearly recognized that it is the remains of the warm deep current which flows westwards into the sea south of 66° S.

In all probability the formation of Antarctic bottom water in the Weddell Sea is largely the result of the warm deep current which flows into the southern edge of the sea and is turned northwards off the east coast of Graham Land.

TEMPERATURE, SALINITY AND OXYGEN CONTENT OF THE ANTARCTIC BOTTOM WATER

Because of the very gradual changes in temperature and salinity with depth between the warm deep and Antarctic bottom layers, it is impossible to give a definite boundary to the layer. The lowest temperature that we have found in Antarctic bottom water in the open sea north of 70° S is −0·55° C. and the lowest salinity 34·65 °/₀₀; salinities of 34·63 °/₀₀ have, however, been found by the German Atlantic Expedition. Above this water there are mixtures with varying amounts of warm deep water. The difference in the properties of the Antarctic bottom layer and the warm deep layer is greater farther north. Wüst (1933, pp. 71 *et seq.*) shows that water which has its origin in the Antarctic bottom and deep layers can be traced as far as 40° N on the western side and as far as 35° N on the eastern side of the South Atlantic. There is, however, only a sharp distinction between the two layers south of the Equator in the west and south of the Walfisch ridge in the east. North of the Antarctic Zone the small discontinuity in the density gradient which shows the boundary between the two layers is found when the temperature is about 1° C. and the salinity 34·70 °/₀₀.

VERTICAL DISTRIBUTION OF PHOSPHATE AND NITRATE IN THE DEEP WATERS OF THE SOUTH ATLANTIC OCEAN

The vertical distribution of phosphate along the meridian of 30° W is shown in Plate IX. North of the Rio Grande ridge the greatest phosphate content is found in the Antarctic intermediate layer, and the warm deep water contains less phosphate. The warm deep water is not therefore the source of the high phosphate concentrations which are found in the Antarctic Zone. Phosphate is added to the warm deep current south of the Rio Grande ridge, and the source of the phosphate is probably in the rich plankton of the Antarctic Zone which decomposes as it is carried downwards at the Antarctic convergence into the bottom of sub-Antarctic water. The decomposition is probably greatest in the region of greatest phosphate content and least oxygen content, that is to say, between the north-going sub-Antarctic and Antarctic intermediate waters, and the south-going warm deep water, between 43 and 38° S. The hydrogen-ion concentration is also greatest between these currents.

The greatest vertical mixing between the two currents also takes place between 38 and 43° S, so that the phosphate is not lost from the Antarctic Zone but is returned to it in the warm deep current.

North of the Rio Grande ridge, where there is a sharper discontinuity between the Antarctic intermediate water and the warm deep water, the surface of the warm deep water is not enriched as much as it is farther south.

In the Tropical Zone the surface stratum is depleted of phosphate, but lower down the phosphate content of the water increases with depth to a maximum of about 120–140 mg. $P_2O_5/m.^3$ in Antarctic intermediate water.

There is a minimum phosphate content at the level of greatest oxygen content in the North Atlantic deep water, and it is probable that the water at this level has most recently been at the surface. In Antarctic bottom water the content increases to 90–100 mg. $P_2O_5/m.^3$

The distribution of nitrate which is also shown in Plate IX is similar to that of phosphate. The greatest concentration is found in 38–43° S between the warm deep water and the sub-Antarctic and Antarctic intermediate waters. Nitrate is returned to the Antarctic Zone in a cycle similar to that which returns phosphate.

The vertical distribution of nitrate shows that the regeneration of nitrate from decomposition products takes place principally south of the Rio Grande ridge: the nitrate content of the water north of the ridge is much less than that of the water south of the ridge.

The surface water in the Tropical Zone is almost depleted of nitrate. Most is found in the Antarctic intermediate layer, and a smaller concentration in the North Atlantic deep water. The bottom water is richer in nitrate than the deep water.

The examination of the nitrite content of sea water has shown that in the Antarctic Zone there can be as much as 6–7 mg. nitrite $N_2/m.^3$ at the surface and 8 mg. nitrite $N_2/m.^3$ at a depth of 80–100 m.; but as soon as a discontinuity appears in the water, which makes vertical mixing with the surface water difficult, no nitrite is found below it. None was ever found below 150 m.

Nitrite was found in sub-Antarctic water in amounts decreasing from 5·5 to 3·5 mg. nitrite $N_2/m.^3$ towards the north. North of the sub-tropical convergence there were only small amounts of nitrite; but farther north, just below the sharp discontinuity at the bottom of tropical water, amounts as large as 30 mg. nitrite $N_2/m.^3$ have since been found. Nitrite is a stage in the formation of nitrate from animal decomposition products, but we have rarely found it at a depth from which vertical mixing with the surface water was difficult. The absence of nitrite from the deep layers in which there are the greatest phosphate and nitrate contents is surprising.

APPENDIX

THE WINDS OF THE ATLANTIC OCEAN SOUTH OF 40° S

By Lieut. R. A. B. ARDLEY, R.N.R.

The accompanying table is compiled from the meteorological logs of the Research ships 'Discovery', 'William Scoresby', and 'Discovery II', and checked from the *Meteorological Charts of the South Atlantic*. In that publication, the data given for latitudes south of 45° S are very meagre, since no trade route lies across the higher latitudes of the South Atlantic. The data extracted from the logs of the three ships of the Discovery Committee, covering a period of seven years, give a good general analysis of wind conditions. A favourable indication of the accuracy of the final average is that though each ship's observations were extracted and compiled separately, the resulting averages for latitude agreed fairly well.

The only other possible source of information concerning oceanic winds in the high latitudes of the South Atlantic would be the logs of the whaling factories voyaging to and from the ice-edge; but in the writer's opinion the averages here given are reliable and would merely be confirmed by further information. The wind forces are measured on the Beaufort Scale.

The relatively high average westerly wind force between the parallels of 40 and 50° S is maintained by the almost constant prevalence of fresh to strong breezes in these latitudes. Between 50 and 60° S, the wind forces are generally more erratic. The region with the highest percentage of gales lies between 45 and 55° S.

The data obtainable are insufficient for compiling an average for easterly winds. Within the latitudes under consideration, easterly winds are usually erratic and of short duration; they blow either as light winds or as brief, violent gales.

In measuring the average force of the westerly winds all winds with a westerly component are taken into account, for it is found that winds from the north-west and south-west quadrants are fairly evenly balanced. Almost all the region north of latitude 55° S lies within the northern semicircles of depressions, and the normal wind sequence, subject to minor variation, is north-west, west, south-west.

South of latitude 55° S, it will be seen that the percentage of easterly winds grows steadily greater. Probably at the Antarctic Circle the easterly and westerly winds are about balanced, and, south of that, easterly winds would predominate.

All the observations collected here were made in spring, summer and autumn, but in this great stretch of ocean it is doubtful if the winter winds would show any large deviation from the average. No account is taken of the ice conditions, though probably when the pack is far north a slightly higher percentage of easterly winds and calms would be found.

The observations cover the whole of the South Atlantic from the meridian of Cape Horn to the meridian of the Cape of Good Hope, and there appears to be no marked difference in the incidence and force of westerly winds in different longitudes. We are however hampered by the paucity of observations in different longitudes.

On the Patagonian shelf, and locally round the Falkland Islands, though strong westerly winds are generally prevalent, they are affected by the proximity of the continent to the westward; the averages are more erratic, and do not agree very well with the averages in the table, which are for oceanic winds. Therefore they have not been included.

South of Cape Horn, within a radius of about 150 miles of the Cape, there are plenty of observations given in the meteorological charts, which agree very well with the results given in Table XII.

Table XII

Westerly winds of the South Atlantic Ocean

Latitude ° S	No. of sets of observations	Average force of westerly winds (Beaufort)	Average force × percentage of westerly winds (Beaufort)	Percentage of easterlies and calms
40	25	4·65	3·94	16
41	18	5·28	4·39	16
42	17	5·13	4·51	11
43	18	5·64	4·35	22
44	18	5·05	4·70	5
45	19	5·08	4·29	16
46	18	5·25	4·93	5
47	22	5·13	4·73	9
48	19	5·45	5·14	5
49	21	5·80	4·65	17
50	29	5·58	4·41	21
51	57	4·85	4·71	2
52	70	4·82	4·58	7
53	105	4·53	3·90	14
54	140	4·64	3·78	18
55	82	5·33	4·44	16
56	74	5·33	4·48	15
57	46	4·61	3·68	20
58	50	4·56	3·55	19
59	43	4·52	3·72	22
60	47	4·21	2·95	30
61	48	4·00	2·37	39
62	37	4·31	2·66	43
63	26	3·97	2·37	43
		Summary for 5° intervals		
40–45	—	5·14	4·37	15
45–50	—	5·38	4·73	12
50–55	—	4·95	4·31	13
55–60	—	4·76	3·81	20
60–63	—	4·10	2·50	39

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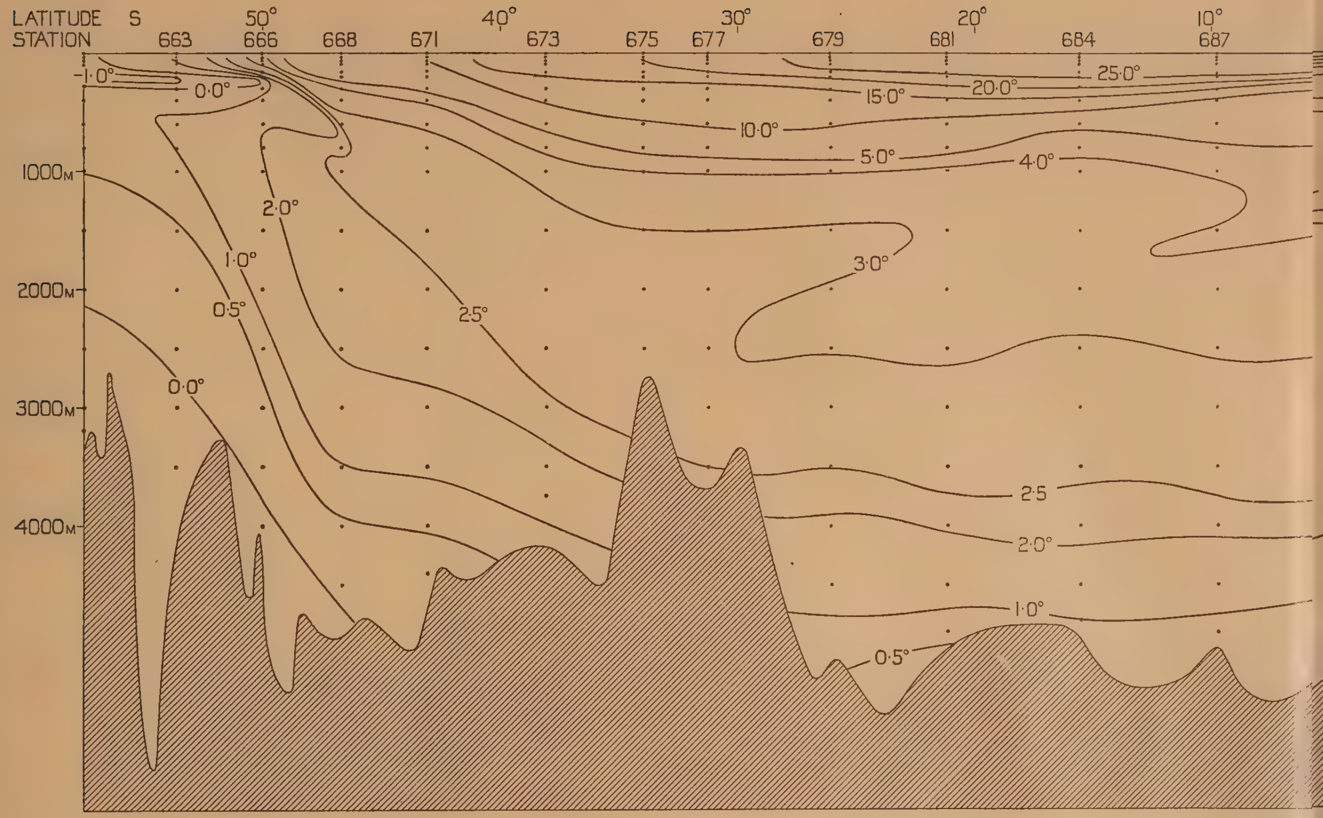


Fig. 1. Section III, distribution of temperature (° C.). April–May, 1931.

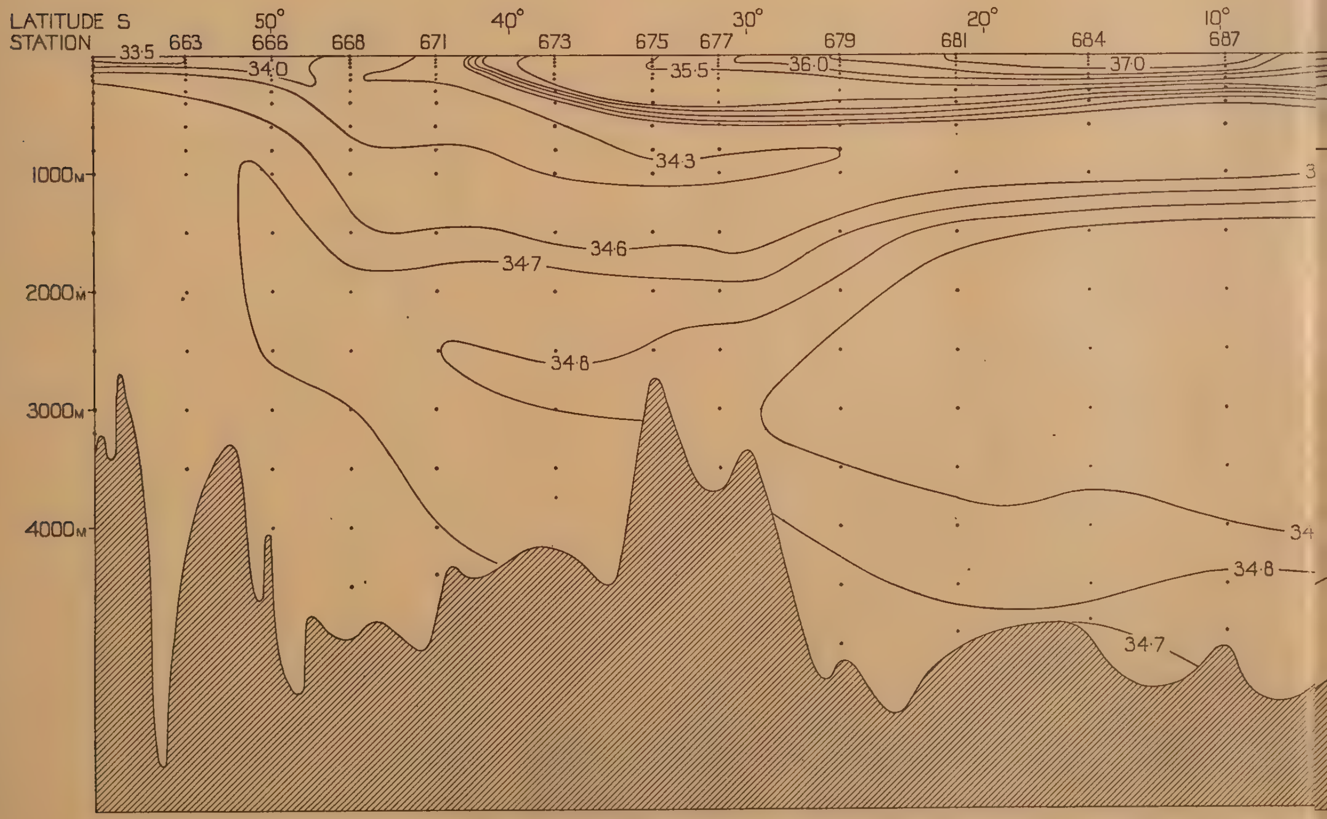
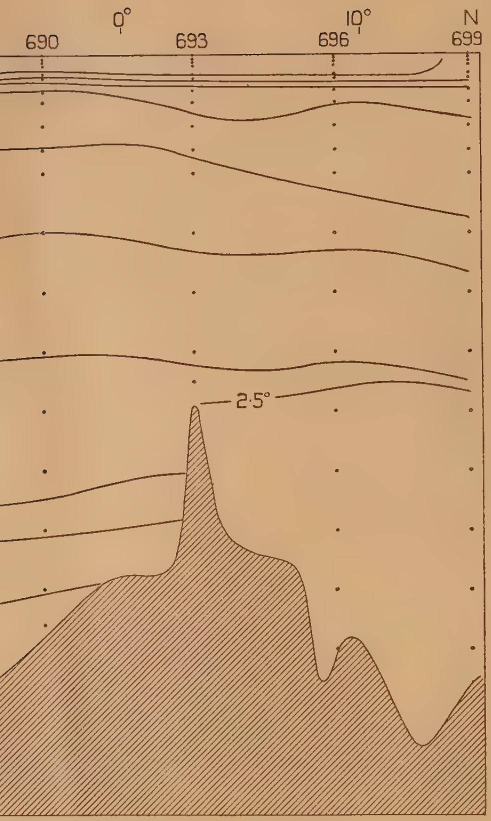
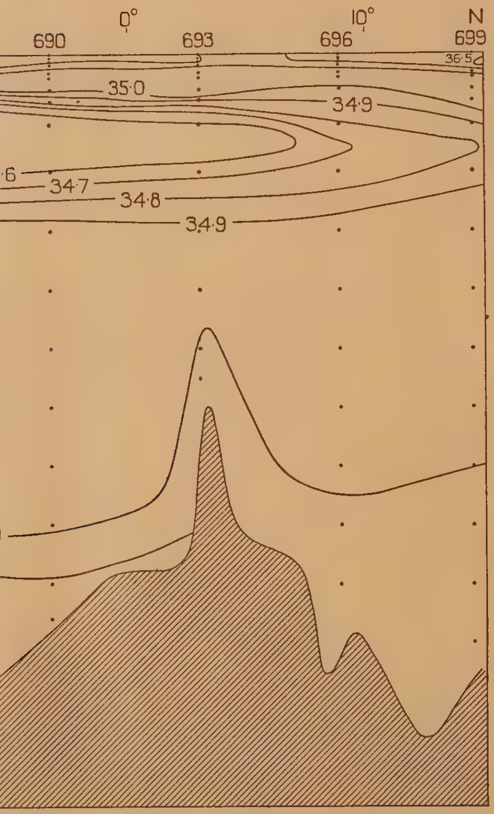


Fig. 2. Section III, distribution of salinity. April–May, 1931.

For position of Section III, see Fig. 11, p. 191.

PLATE VIII


0°
10°
N
690
693
696
699
2·5°


0°
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·6
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34·8
34·9

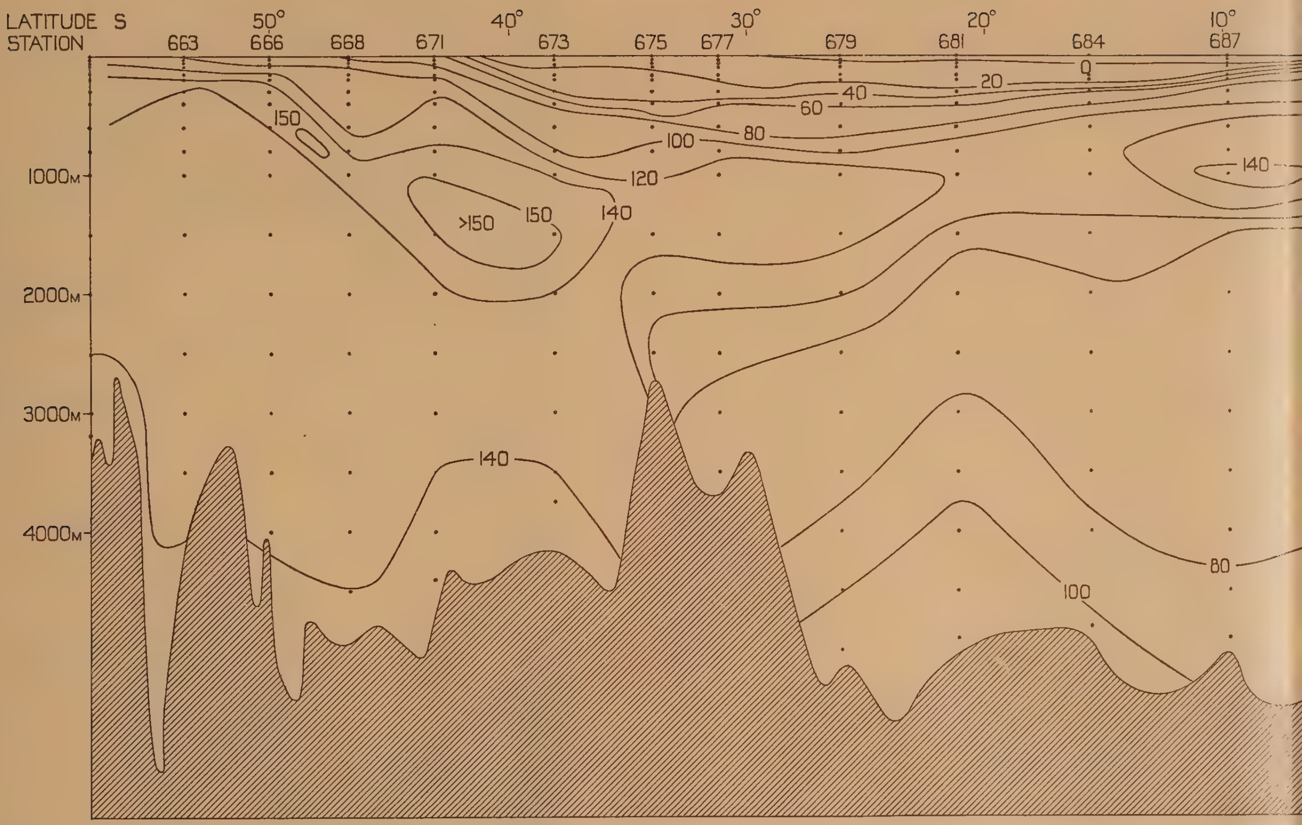


Fig. 1. Section III, distribution of phosphate content (mg. $P_2O_5/m.^3$). April–M

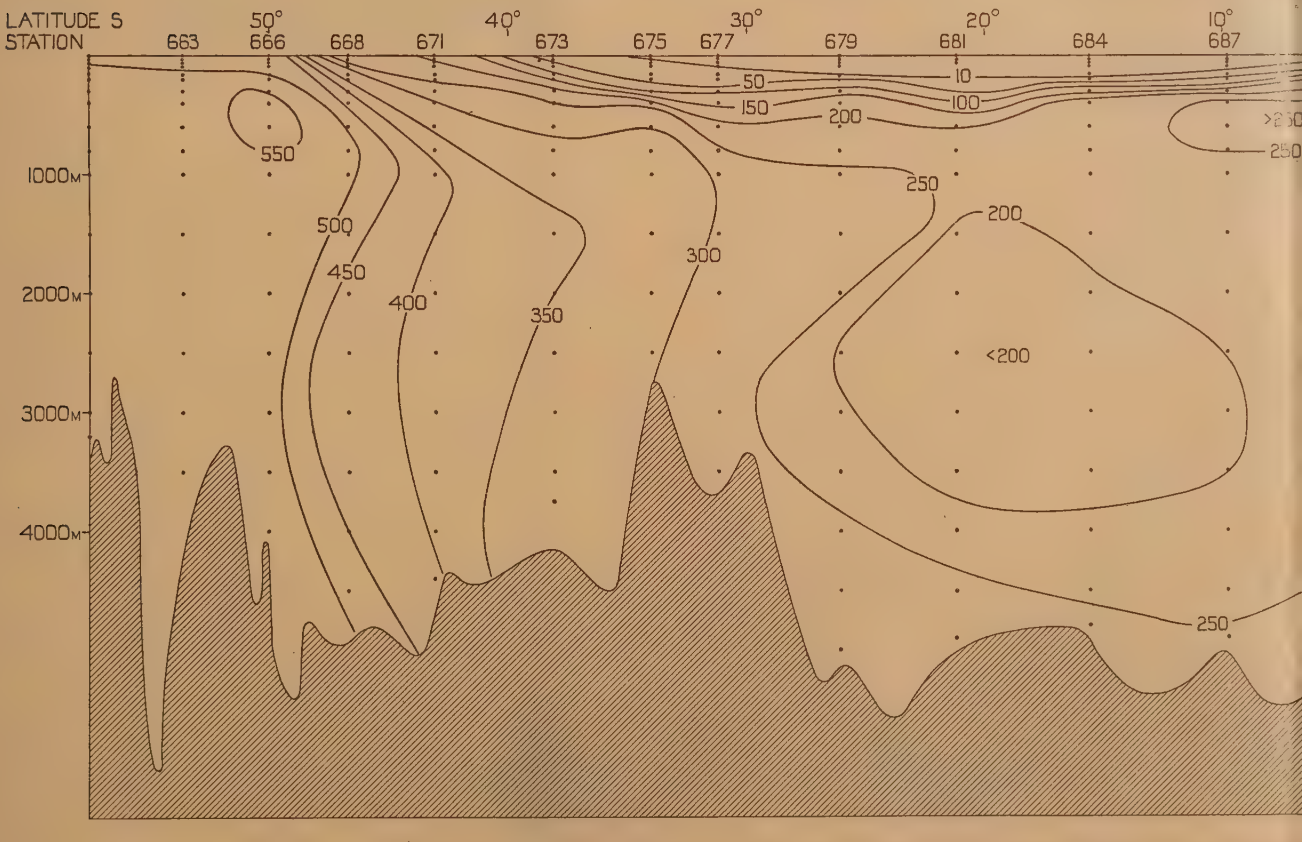
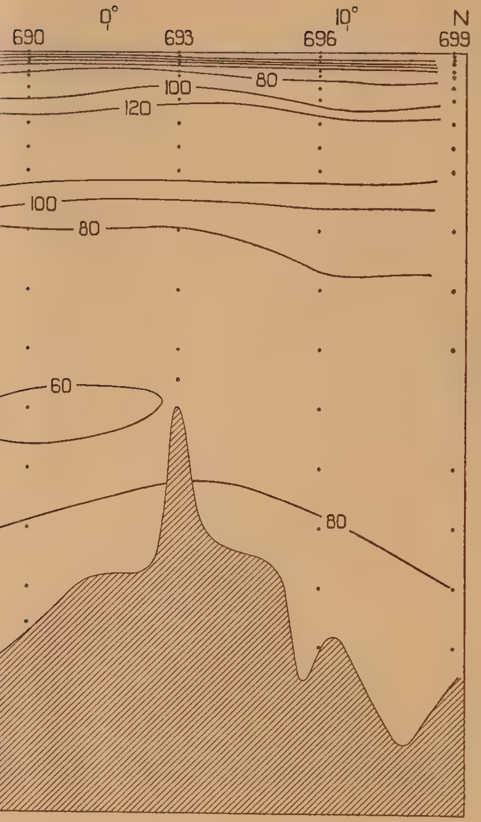
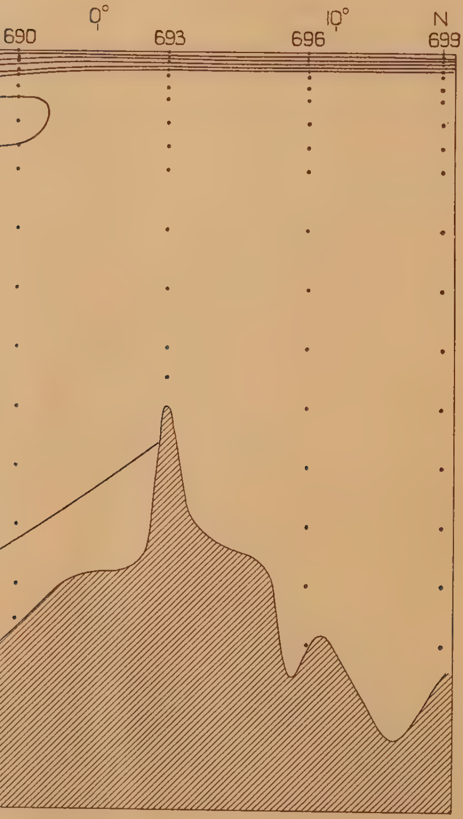


Fig. 2. Section III, distribution of nitrate content (mg. nitrate + nitrite $N_2/m.^3$). April-

For position of Section III, see Fig. 11, p. 191.

PLATE IX





1931.

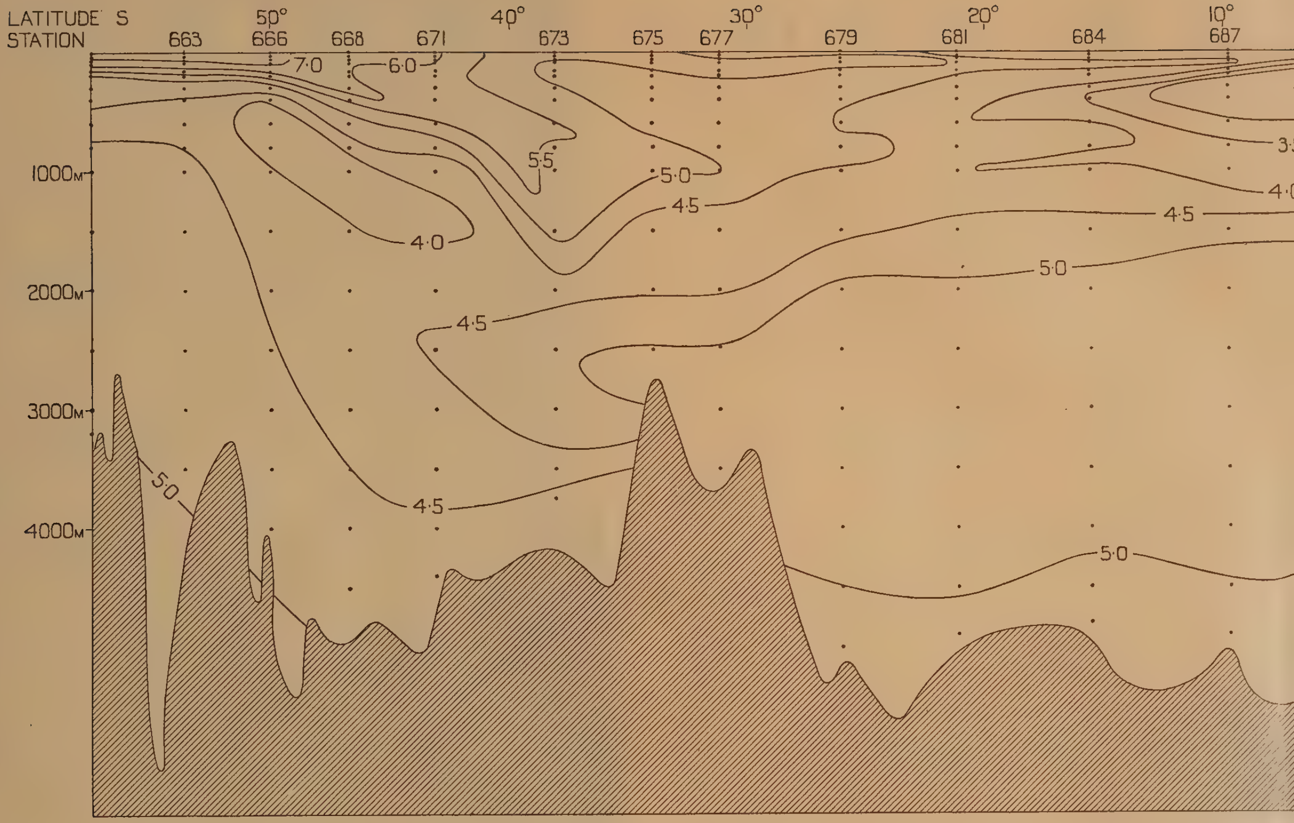
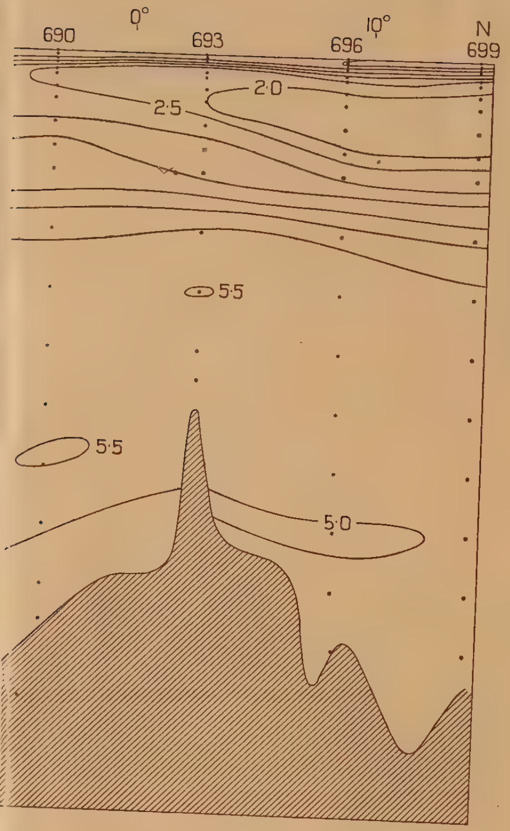


Fig. 1. Section III, distribution of oxygen content (cc. O_2/litre). April–May,

For position of Section III, see Fig. 11, p. 191.

PLATE X



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WHALING IN THE DOMINION OF NEW ZEALAND

By

F. D. OMMANNEY, A.R.C.S., B.Sc.

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WHALING IN THE DOMINION OF NEW ZEALAND

By F. D. Ommanney, A.R.C.S., B.Sc.

(Plates XI–XIII; text-fig. 1.)

INTRODUCTION

THE following account does not pretend to be more than a brief outline of the history of the whaling industry in New Zealand from the beginning of the nineteenth century, and a sketch of the small industry as it exists to-day. No claim is made that it embodies in any way the result of direct observations made by the author.

The chief sources of information in the first section of the paper were Dr Robert McNab's *The Old Whaling Days* (Whitcombe and Toombs, Melbourne and London) and the writings of Dr Ernest Dieffenbach (*Travels in New Zealand*, Murray, London, 1843), who was naturalist on board the 'Tory', the exploration ship of the New Zealand Company. In addition to the above very little has been written on the subject of whaling in the Dominion. A few other references, however, were used and appear in the list of literature.

The second section of the paper, dealing with the two modern whaling stations, is compiled almost entirely from conversations with Mr H. F. Cook, manager and part owner of the station at Whangamumu, who visited the R.R.S. 'Discovery II' at Auckland, and with Mr Joseph Perano, owner and manager of the whaling station at Te-Awaiti, Tory Channel.

The author takes this opportunity of thanking these gentlemen for their courtesy in supplying information and for their interest in the work of the Discovery Committee. When the R.R.S. 'Discovery II' was at Wellington in August 1932 some of the scientific staff, including the author, paid a visit to Te-Awaiti and were received by Mr Perano and his family with the greatest hospitality. The author is also indebted to Messrs A. W. B. Powell and R. A. Falla, of the Auckland Museum and Institute, who reviewed the manuscript of this paper and made certain corrections.

HISTORY

Attention was first drawn to the whaling grounds of New Zealand by the writings of Cook, who visited the islands in 1770, 1773 and 1774. In 1791 a fleet of whalers, bound for the coast of South America, was carrying convicts and stores to Australia. They reported great numbers of Sperm whales in Australian waters. After the convicts and stores had been landed they made a trial of the grounds, but reported that, while whales were abundant, the weather was too bad for profitable fishing. They continued to the old grounds off the coast of Chile and Peru.

In 1798 it became no longer possible for whalers to recruit their ships at Pacific ports owing to the war between England and Spain. Until that year whalers had been prevented from operating in Australasian waters by the limits imposed by the British East India Company, who controlled by permit all whaling operations between longitudes 51° and 180° E. New Zealand Sperm whaling thus really dates from the year 1798, when, as a result of the reported presence of Spanish warships off Cape Horn, whalers were instructed to pass into Australasian waters for the duration of the war (McNab, 1914).

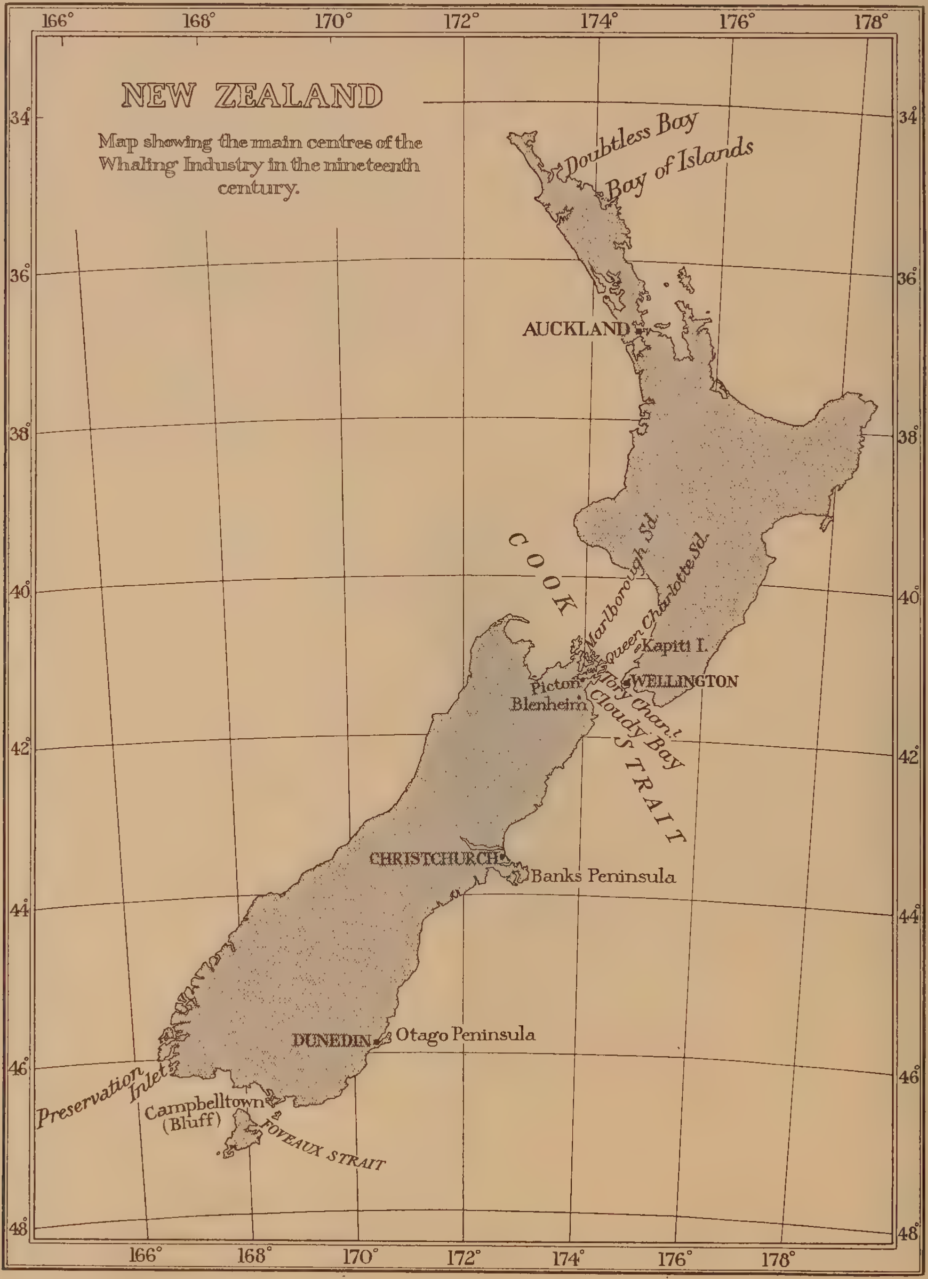
NEW ZEALAND
Map showing the main centres of the Whaling Industry in the nineteenth century.
166°
168°
170°
172°
174°
176°
178°
34°
36°
38°
40°
42°
44°
46°
48°
Doubtless Bay
Bay of Islands
AUCKLAND
COOK STRAIT
Marlborough Sd.
Queen Charlotte Sd.
Kapiti I.
WELLINGTON
Picton
Blenheim
Tory Chan.l
Cloudy Bay
CHRISTCHURCH
Banks Peninsula
DUNEDIN
Otago Peninsula
Preservation Inlet
Campbelltown (Bluff)
FOVEAUX STRAIT

Fig. 1

The Sperm whaling trade was carried on mainly by British and American ships, while a small though increasing proportion was done by Sydney and Hobart firms (McNab, 1913, p. 260). The Sperm whalers called mainly at the Bay of Islands at the northern end of the North Island, but also at Doubtless Bay in the extreme north, and at Cloudy Bay at the northern end of the South Island. This latter locality, with the neighbouring Queen Charlotte and Marlborough Sounds, later became the main centre of the New Zealand Right whale industry. The Sperm whalers established bases in these bays at which the ships could be repaired and careened, and arrangements were made with the natives for the supply of foodstuffs, the whalers trading iron for potatoes and flax (McNab, 1914). The natives often went aboard the whaling ships to assist in the disposal of the carcase and the getting of the oil.

At the end of the third decade of the nineteenth century (1827–30) the number of Sperm whales in New Zealand waters became seriously diminished (McNab, 1913, p. 2), and the increasing demand for Right whale oil and whalebone drew greater attention to the habits and pursuit of the southern Right whale. The year 1830 saw the beginning of the Right whale industry, which, for some years, continued side by side with Sperm whaling and finally became the more important of the two. Right whaling continued as a flourishing industry until 1840, when ruthless overfishing began to tell seriously upon the stock. The fishing was carried on both in the open sea and among the bays and sounds around the coast (bay whaling). The vessels engaged in the trade were at first almost all fitted out and owned at Sydney or Hobart. In the year 1834 the first British and American vessels took part, and after that year the number of American ships whaling around New Zealand steadily increased. In 1840 there were between six and seven hundred American whalers distributed around the coasts of the two islands (Condliffe, 1930, p. 115). This was about half the total number for all nations. The Americans carried on most of their operations at Cloudy Bay in Cook Strait, but also at Kapiti Island and farther south at Banks Peninsula or Bluff Harbour or farther north at the Bay of Islands and Doubtless Bay. The British whalers never seriously rivalled the Americans, even when a tariff of £26. 12*s.* 0*d.* per ton was introduced by the British Government upon oil carried in foreign ships (McNab, 1913, p. 261). In 1838 a number of French ships were operating at Banks Peninsula and the corvette 'Héroïne' was sent out "to overlook the interests of France and to maintain order in, and give help to, their numerous whalers in the South Pacific". Portuguese and Dutch ships also entered the business at about this time.

BAY WHALING

Much of the Right whale industry was carried on by the method known as "bay whaling". This branch of the fishery derived its name from the Right whales' habit of entering shallow bays and inlets along the coast for the purpose of giving birth to their calves. "These fish", wrote Dieffenbach (1843, p. 47), "approach the shores and bays with the flood tide and quit them with the ebb...they are often seen in places where the depth of the water does not much exceed their own breadth, rubbing their huge bodies against the rocks and freeing themselves from the barnacles and other parasitical animals with which they are covered". The Right whales arrived off the coast of New Zealand at the beginning of May from the northward, and the cows entered the bays to calve throughout May, June and July. Nearly all the Right whales killed were cows with their calves, since the bulls rarely approached the land so closely and were much more shy and wild. The cows were joined by the bulls later in the season and both cows and bulls put to sea together. In October and November they returned north and east, some through Cook Strait and some through Foveaux Strait. According to Dieffenbach they began to show themselves at the Chatham Islands from June onwards and their numbers increased in that locality towards the end of the season. "During the six remaining months of the year the ships cruising in the 'whaling ground' fall in with many whales. This whaling ground extends from the Chatham Islands to the eastward of the North Island of New Zealand and thence to Norfolk Islands."

Whaling operations were carried on from ships anchored in the bays, particularly Cloudy Bay or the Bay of Islands, or from stations established on shore. These shore establishments eventually became very numerous and came to resemble well-equipped factories with houses and plant erected in suitable bays, from which the bay whaling could be carried on by means of a number of boats. In the early bay whaling days, however, they were no more than try pots erected on the beach with huts for the storage of whaling gear and boats. McNab quotes a Mr Bell, who owned a station in Cloudy Bay, and who gave a description of bay whaling. "If the fishing is to be carried on by means of a shore party the try pots and huts are erected on the beach and the vessel which brought the party down is either employed in collecting flax along the coast or returns to Sydney and is sent down again at the end of the season to bring them up with what oil they may have caught. The boats are sent out at daylight every morning and, when they are so fortunate as to kill a fish, it is towed ashore and 'flinched' and boiled up on the beach. When the fishing is carried on in a vessel the blubber is boiled in try pots erected on deck as in a Sperm whaler....The whales are seldom killed nearer than two miles from the harbour and sometimes seven or eight....The depth of the water in the bays where the whales are killed is 14–20 fathoms." Look-out posts were established on an elevated part of the coast near the plant or the anchorage so that warning could be given when the spout of a whale was seen. The operation of "flensing" or "cutting-in" was presumably carried out in the manner described by Scammon (1874, p. 235) at Californian bay whaling stations, since Dieffenbach mentioned the "shears", a gallows or scaffolding erected near the shore, by means of which the carcase was suspended at the surface of the water. It could then be turned and rolled over by tackle while the blubber was being stripped off. When the whaling was carried on from a ship the shears were lowered over the side. "The blubber was cut off in square pieces by means of a sharp spade, carried to the shore and put into the try pots" (Plate XIII, fig. 2). At American whaling stations the blubber was cut off in a series of spiral folds.

That this was the method of flensing employed by the bay whalers seems fairly certain from Plate XIII, fig. 2, which illustrates the process being carried out in the early days of the modern station at Whangamumu, Bay of Islands. The shears can be seen in the background, while the blubber of one of the carcases is being cut into square sections.

The yield of oil per whale varied from two to thirteen tons and averaged six tons. Cows were larger than bulls and yielded more oil, but became thin towards the end of the season from supporting the calves. "It is a pity", wrote Mr Bell, "that it should often be necessary to fasten to the calf in order to secure the cow." The whalers made a practice of taking the calf first since it was inexperienced and slow, and the cow then became an easy prey, refusing to leave the calf. The boat which killed the calf claimed the cow, even if the latter were captured by a different crew.

With the development of bay whaling, more elaborate shore stations were established all round the coast, especially at Preservation Inlet, Cloudy Bay, Otago and Marlborough Sound. Many of them were well-equipped factories employing, perhaps, a hundred Europeans. The earliest shore stations were established in New Zealand about 1830 at Te-Awaiti in Tory Channel, and at Preservation Inlet. At the latter place there was a dwelling-house for the manager and his family and a large storehouse. There were also six houses for the use of other whaling companies and a shed for sixteen boats (McNab, 1913, p. 85). Thus it seems that at some at least of the stations accommodation was available for the use of whaling ships. Dieffenbach (1843, p. 371) records that at the Te-Awaiti station some of the houses "were substantial wooden buildings, but the majority had thatched walls of liands and bulrushes".

Preservation Inlet employed some fifty or sixty Europeans, who were engaged in sealing or sawing timber when the whaling season was over. At Te-Awaiti, however, Dieffenbach wrote that in the summer season the whalers lived "dispersed over the (Queen Charlotte) Sound, sometimes trading in a small way with passing ships in potatoes and pigs...but more generally passing their lives in idleness". Most of the stations possessed a ship which brought stores from Australia and took back oil at the end of the season. The main lines, in fact, upon which the stations were run do not seem to have been very different from those of a modern Norwegian shore station. Each one manned perhaps half a dozen boats.

Each boat's crew at most of the stations, as on the ships, consisted of the usual five or six oars (either Europeans or natives), a "headsman" or "boat-header", who was officer-in-charge, and a "boat-steerer". The headsman and steerer were always Europeans. Scammon (1874, p. 226) wrote, "The officer-in-charge, or boat-header, in the stern...steers the boat with the steering oar, which is usually 22 ft. long; the boat-steerer pulls the oar farthest forward, which is called the harpooner oar. (The boat-steerer) darts the harpoon, and, after the boat is fast, changes ends with the boat-header and steers the boat while the latter attends to killing the whale". Scammon was writing of the Californian bay whalers, but the methods used in New Zealand seem to have been the same.

The whalers in New Zealand came into close contact with the natives and often into conflict with them. The Maoris made frequent raids upon the shore stations and burnt down buildings; but they also traded with the whalers for fire-arms, supplying in return potatoes and vegetables generally. The Maoris, also, in many places, used to engage in whaling on their own account and sell their captures to the whaling ships or to the shore stations. At Te-Awaiti they used to obtain £20 apiece for the carcases of the whales which they took.

The whalers used to arrange with the local chiefs for the use of their coves and bays for whaling, and McNab records that these arrangements not infrequently led to jealousies and feuds between the chiefs. The natives supplied the whalers with wood, fuel and water, and often came on board the ships to assist in dealing with the carcases. In this connection McNab states that the American whalers were at a serious disadvantage compared with their Australian competitors because they lacked intimate knowledge of the Maori and of his language. Owing to the great distance from their home ports the Americans were especially dependent on the natives for food supplies and the recruiting of labour. They frequently had to make use of interpreters and, in Cloudy Bay, there were two or three men who acted in this capacity. These interpreters were usually Europeans, runaways from ships, and were locally known as "tonguers". Each "tonguer" had a boat and a number of natives attached to him. On the arrival of a vessel in Cloudy Bay he went on board and canvassed for employment, which consisted of interpreting and furnishing a boat's crew to help to tow in the dead whales and to cut them up. The remuneration for these services was the carcase and tongue of the whale. Only the blubber was taken by the whalers and the tongue was left untouched. This provided the "tonguer" with about six or eight barrels of oil.

McNab records that, although American and English whalers were carrying on their trade side by side during a time when their countries were at war, the most friendly relations existed between them. They seldom quarrelled and frequently formed treaties of mutual assistance, under which they helped to tow in each other's whales and combined against the assaults of the natives.

The year 1839 saw the maximum development of the Right-whale industry in New Zealand. After 1840 its history is only that of a steady decline resulting directly from overfishing. In 1892, the first year for which figures are given in the *New Zealand Year Book*, the whaling industry in the Dominion had become insignificant, 3100 gallons of Sperm-whale oil and 1572 gallons of Right-whale oil being taken.

In the years immediately before the war of 1914–18 the attention of Norwegian whalers was directed towards the waters around New Zealand. The rapid development of the South African fishery during the years 1908–11 led to the supposition that a similar whaling ground would be found to exist off the coast of the Australasian land masses, to which whales from the Antarctic Ocean would migrate during the southern winter. The somewhat vague reports brought back from these waters by sealers and others, and the knowledge that flourishing Sperm and Right-whale industries had once existed in this region, encouraged several firms to fit out costly expeditions to explore the seas around Australia and New Zealand. Risting (1922) gives some account of these ventures, all of which met with disastrous failure.

The A/S 'Laboremus', in the autumn of 1911, sent the sealer 'Mimosa', fitted out as a floating factory, with a whale-catcher, to explore the coast of Tasmania. She failed to find whales around Tasmania and explored the New Zealand seas without any success. The "New Zealand Whaling Company" of Larvik, under the same management as the "West Australian Whaling Company", sent the factory ship 'Rakiura' and four whale boats to New Zealand in March 1912. The ship was for a time stationed in the Bay of Islands, and Lillie (1915) records its presence there during the months July to October, 1912, when he visited the Whangamumu whaling station. Lillie mentions also the sailing ship 'Prince George' with which the company was apparently also working in the Bay of Islands at that time. The 'Rakiura' worked only for one season and thoroughly explored the seas around New Zealand from the Antarctic to the Kermadec Islands in the north and Campbell Island in the east. No success was met with, however, and the Company abandoned the area and obtained whaling rights on the west coast of Australia, becoming the "Fremantle Whaling Company". Another expedition also met with failure—that of the A/S 'Australia', which fitted out a ship, the 'Loch Tay', and two whale boats, to explore the eastern coast of Australia. After extensive voyages over the whole area, southward to New Zealand and eastward to Campbell Island, the expedition went to Bluff, in the South Island of New Zealand, and for a short time, from January to April 1913, carried on a small Sperm-whale fishery.

These failures were made only a little less disastrous by the discovery of pieces of ambergris on one or two occasions. They demonstrated beyond question that the number of whales to be found in Australasian waters is much too small for large-scale undertakings, and no further attempts have been made to exploit the region on these lines.

MODERN WHALING IN NEW ZEALAND

There are at present two whaling stations operating on a small scale in New Zealand. The older of these two stations is situated at Whangamumu, Bay of Islands, and the younger in Tory Channel, Queen Charlotte Sound, at the northern end of the South Island. In the bay whaling days there were several shore stations in the Tory Channel near the site of the modern one.

The Whangamumu station was established by Mr H. F. Cook in 1890, and is still managed and part-owned by him. Mr Cook shipped to New Bedford and back in one of the last American Sperm-whaling ships which visited New Zealand before he started his own whaling factory. The station was not operating during the winter of 1932 so that no visit was made to it, but something of the methods employed there was learnt from a conversation with Mr Cook in Auckland. D. G. Lillie, in the winters of 1911 and 1912, visited the Whangamumu station and the factory ship 'Rakiura' when she was lying in the Bay of Islands. He made a study (Lillie, 1915) of the Humpbacks brought in during the time he was at Whangamumu, and his account is confirmed in many respects by that which follows. The station was established for the purpose of taking the Humpback whales which come close in shore along the coast of New Zealand. Right whales and Blue or Fin whales are very rarely taken. The total catches at both of the New Zealand stations are very small, seldom exceeding 70 whales, and averaging about 50 whales, in a season.

At Whangamumu open boats and hand harpoons were used at first for the capture of Humpbacks. The method used was an unusual one. A rope cable was stretched between a rock and the shore, across a channel some 50 yards wide, or was buoyed out from the shore in positions where whales were known to pass regularly and were likely to be intercepted. Sections of net were suspended from the cable and the whales became entangled in them (Plate XIII, fig. 1). In their struggles to free themselves they used to carry away sections of the net, so that their progress was impeded and they became an easy prey for the harpooner. The nets were at first made of rope but later meshes made of 1 in. wire, shackled together, were found to be more durable and less bulky. A similar process has been used in Japan for the capture of Humpbacks in shallow channels (Möbius, 1893). However, the largest annual catch by means of the nets was only nineteen whales.

In 1910 a steam whaler was built for the firm and the use of the nets was abandoned. The station now uses this catcher and two fast motor-boats mounted with light harpoon guns. These boats are of the same type as those used by the Te-Awaiti station, illustrated in Plate XI, fig. 2. The average catch per season amounts to 50 to 60 Humpback whales, while 70 is a record catch. About 5 tons (30 barrels) of oil per whale are obtained. The whole of the carcase is used, the blubber being reduced in open boilers and the meat and bone in pressure boilers. Bone meal and guano are made from the residues. The station is modelled upon Norwegian lines but is on a relatively very small scale. The workers are all Maoris whose families have been in the firm's employment since the inception of the station.

The station operates for two separate periods each year. The first period covers the months of June, July and part of August. The second period begins on October 1 and continues until the end of November. During the first of these two periods the whales are travelling northwards. Lillie wrote (p. 110), "The first whales began to pass the Bay of Islands on their way northward about the middle of April. They continued to go north until the end of August. The greatest number passed northward of this locality in May and the early part of June". During the October–November period the whales are travelling southwards. "After the middle of September", continued Lillie, "at the Bay of Islands, the first members of the long procession were seen going southwards. The majority passed south of the Bay during October and by the middle of December they were all south of this place."

The direction of the Humpbacks' seasonal migration is thus opposite to that of the Right whales but occurs at the same time of year. At the beginning of the season the majority of the cows are carrying large foetuses. In July Lillie saw a foetus 13½ ft. in length; the length of the Humpback calf at birth being about 15 ft. During the southward migration the majority of the cows are lactating and the calves not much more than 15 ft. long—evidently newly born. Mr Cook stated that many of the cows with sucking calves of about this length are also carrying foetuses about 2 in. in length. In October Lillie saw a foetus 2½ in. in length. The south-bound whales have a greater or lesser quantity of food in the stomach, while the stomachs of the north-bound whales are nearly always empty. Matthews (1932), from the various accounts given to him, identifies the food of New Zealand whales as the Grimothea larva of *Munida gregaria*. This animal occurs in shoals around the coast and Mr Cook spoke of it as colouring the sea red. The present author had no opportunity of verifying any of the somewhat confused descriptions which he heard of this "whale feed", but Matthews is in no doubt about its identity.

Occasional Right whales are taken at the Whangamumu station. When the steam whale-catcher was first built Mr Cook made an expedition with it to Campbell Island, having heard reports of numerous Right whales in that area: the expedition was, however, unsuccessful.

During the month of June, around the Friendly Islands, the copulation of Humpback whales has been observed. According to Mr Cook the animals lie together in the water obliquely with the axes of their bodies at an angle of about 45° with the surface and their ventral surfaces apposed, so that only their heads project. The male assumes the uppermost position and embraces the female with his flippers.

The Tory Channel whaling station at Te-Awaiti was established in 1909 by Mr Joseph Perano, who was a fisherman without previous experience of whaling. He has evolved a unique method of chase and capture without any knowledge at all of Norwegian methods.

Shore whaling stations were situated in Tory Channel in the old bay whaling days. The region of Queen Charlotte and Marlborough Sounds is remarkable in that it is an area of very recent post-Pleistocene subsidence, which "drowned" the valleys between the mountains, leaving in their place long parallel fjords, often less than two miles across. The Tory Channel is a narrow strip of water at the outer end of this system of fjords connecting Queen Charlotte Sound with Cook Strait. The whaling ships found these tortuous channels difficult to negotiate and resorted to the more convenient Cloudy Bay. Tory Channel was therefore left entirely to the shore establishments and, during the bay whaling period, quite a large number of stations were operating in the channel. When they were all fully working and bay whaling was at its height some twenty boats used to go out from Te-Awaiti alone. The earliest station at Te-Awaiti was that of Captain John Guard, who was driven into Tory Channel in 1827, when in command of a sealing expedition. He built a home for himself and, as seals became scarcer in the neighbourhood, took up the chase of the Right whale, "with great risk and annoyance from the natives", who frequently burnt down his buildings, "and no profit to himself". He was unable to keep the oil of the whales he killed, owing to lack of men and gear, and took only the baleen which he sold to passing ships (McNab, 1913,

p. 297). Guard was succeeded at Te-Awaiti by Messrs Barrett and Thoms, who were also at first without resources and killed the whales only for their baleen (Dieffenbach, 1843, p. 39). Later, however, speculators in Sydney supported them with gear and ships for the transport of oil. Besides the two stations of Barrett and Thoms at Te-Awaiti there were others, and one in the adjoining cove Jackson's Bay. The Maoris also from the adjoining "pas" or villages used to pursue whales on their own account with their own boats, selling their captures to the stations for £20 each. All these stations, however, fell into disuse when bay whaling came to an end about 1840.

The modern station at Te-Awaiti operates only during June, July and August. There is no second appearance of the Humpback whales during October and November as at Whangamumu, apparently because they do not pass through Cook Strait during their southward migration. In June, July and August they are travelling northwards, as at the Bay of Islands, and appear in Cook Straits usually on the flood tides. Mr Perano said that most of the whales taken by his station are bulls. Such cows as are caught are carrying large foetuses about 14 ft. in length. A few Southern Right whales are taken, especially towards the end of the season.

The method of capturing and killing the Humpbacks which Mr Perano employs is so different from the Norwegian method that some description of it may be worth while. As is well known, the Norwegians use fast steam whale-catchers with a heavy harpoon gun mounted in the bow. The harpoon is fired by means of a charge of black powder and has, at its head, three hinged iron barbs which are lashed to the stem of the harpoon. The barbs become unlashed on entering the whale's body and project outwards so as to prevent the withdrawal of the harpoon. In front of the barbs at the head of the harpoon is a heavy conical grenade of cast iron, filled also with black powder and exploded by means of a time fuse. The fuse is ignited by the discharge of the harpoon from the breech of the gun. The whale is killed by explosion of the grenade after the harpoon has entered its body. The harpoon carries out with it a stout rope line which is coiled in a hold of the ship abaft the gun-mounting and runs from the hold to the gun round the drums of the steam winch and over a system of accumulator blocks fitted to the mainmast. The first fifty fathoms of this line are of smaller diameter than the remainder and are coiled in readiness upon a platform in front of the gun mounting. This lighter rope is the "forerunner" which is carried out by the harpoon immediately it leaves the gun. After the whale has been struck the rest of the harpoon line follows and the whale is, as it were, "played" like a fish at the end of the harpoon line. He usually "sounds", or dives deeply, after being struck, or thrashes about in the water. If the harpoon has not hit fairly into the back it may be necessary to fire a second harpoon. If that is so the whale is hauled within range by the harpoon line wound upon the drum of a steam winch. After the death of the animal the carcase is made fast by the tail alongside the ship, the flukes being cut off for convenience. The body wall is pierced by a long lance carrying the end of a pipe leading from an air pump. Air is pumped into the carcase so as to render it buoyant, since, after expulsion of the air from the lungs, the carcase of the Blue or

Fin whale sinks. The carcase is then towed back to the whaling station tail foremost alongside the ship.

The Norwegian method is not suitable for use in the narrow Tory Channel and the shallow bays around the Queen Charlotte Sound where the Humpback whales are found. Mr Perano uses three fast motor launches, 34 ft. long and capable of maintaining a speed of 30 to 40 knots (Plate XI, fig. 2). These boats can be stopped or turned almost within their own length. Each has a light harpoon gun ($1\frac{1}{4}$ in. bore) mounted in the bows (Plate XII, fig. 3). The harpoon is similar to that used by the Norwegians but much lighter in build (Plate XII, fig. 4). It has slightly curved barbs and the cast iron grenade is triangular in section. The harpoon line, which is considerably lighter than that used by the Norwegians in their steam catchers, is coiled in the stern of the launch and pays out from that position when the shot is fired. The explosion of the grenade stuns but does not kill the whale. After the shot the launch is brought up close to the whale and the body is inflated with air in the Norwegian manner. After inflation the whale is finally despatched by inserting into the thorax ventrally a long lance with a hollow cast iron head. The head is filled with a pound and a half of gelignite which is exploded within the whale's thorax by means of an electric detonator. The carcase is then towed back to the station tail foremost at the stern of the launch.

Mr Perano and his two sons encamp during the season on a headland overlooking Cook Strait, where they keep a look-out for whales spouting. As soon as one is sighted they put out in pursuit of it in their launches which are anchored below. When Mr Perano's station was first established there was, for some years, a rival station on the other side of Tory Channel, and Mr Perano told the writer of races between the boats of the rival stations for the same whale. These trials of skill were frequently attended with great risk and damage sometimes occurred, nor did the fact that the other station was owned by Mr Perano's brother diminish the keenness of their rivalry.

The above method of pursuit and capture is very successful for the chase of the Humpback or Southern Right whale, especially within a confined space such as the Tory Channel, but Mr Cook, who works more in the open sea around the Bay of Islands, has been more successful with the steam chaser. Southern Right whales can be towed easily by the launches since they float when dead. Humpbacks float just long enough to enable them to be inflated with the small gear available. Blue and Fin whales apparently sink almost immediately and have to be towed back along the bottom of the channel with great difficulty.

The factory plant itself at Te-Awaiti (Plate XII, fig. 2) is very small. There are two pressure boilers, a small flensing slip and three storage tanks. The capturing and dismemberment of the whales and the general work of the station is done by Mr Perano and his two sons, with the assistance of a small staff of Maoris. Only the blubber of the whale is used and the oil is sold in Australia, where it is used mostly in the manufacture of hemp rope.

It is, perhaps, not out of place to conclude this short account by recording two instances of recovered harpoons which Mr Perano related to the writer. They are remarkable in that they seem to point to the fact that Humpbacks at any rate, if they do not use fixed migratory routes, are at least in the habit of returning at intervals to the same place. Before the introduction of the harpoon with the explosive grenade, Mr Perano used a type of hand harpoon. This had an S-shaped head swivelled about its centre at the end of a long shaft. With this harpoon it sometimes happened that whales were lost and carried the harpoon away inside them. It was not, however, a very successful pattern and its use was practically discontinued after the introduction of the grenade. At any rate no whale was lost with one of these hand harpoons inside it after the introduction of the grenade. Mr Perano stated that a Humpback had been taken at Te-Awaiti, not very long before the visit of the writer to the station, with a swivel head embedded in the musculature, and that this harpoon must have been fired at least eighteen years previous to the capture of the whale. He was able to identify the harpoon head as one of his own.

When the explosive grenade was first introduced at Te-Awaiti a pattern was used which had three flanges about its tip. Its use was discontinued when the triangular grenade replaced it. The flanged pattern was not successful and was only used for one season. Seven years after that season a Humpback whale was taken in which was found a portion of a grenade of the flanged type. A harpoon grenade of that pattern was not used at any other whaling station or factory. These two harpoon heads are now in the Auckland Museum.

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PLATE XI

Chasing Humpback whales off the coast of New Zealand.

Fig. 1. The whale "sounding" after being struck, throwing the tail flukes clear of the water.

Fig. 2. The whale has "sounded" and the slack line is being hauled in. The photograph illustrates clearly the type of motor launch used at the New Zealand stations.

Fig. 3. The whale has returned to the surface after the "sound", his nose protruding above the surface in his struggles. The gunner is preparing to fire a second shot.

Fig. 4. The whale has been stunned, but not killed, by the explosion of the harpoon grenade inside its body. The body is now being inflated with air.

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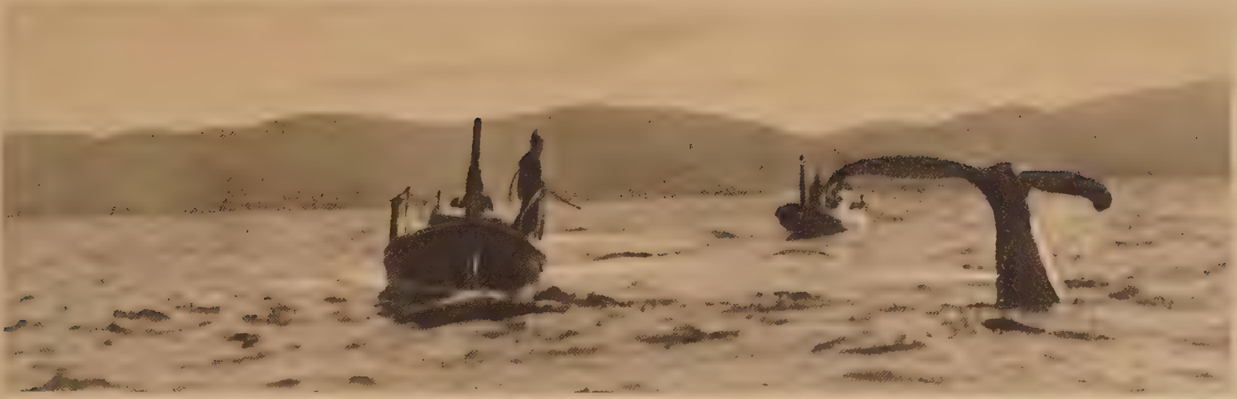

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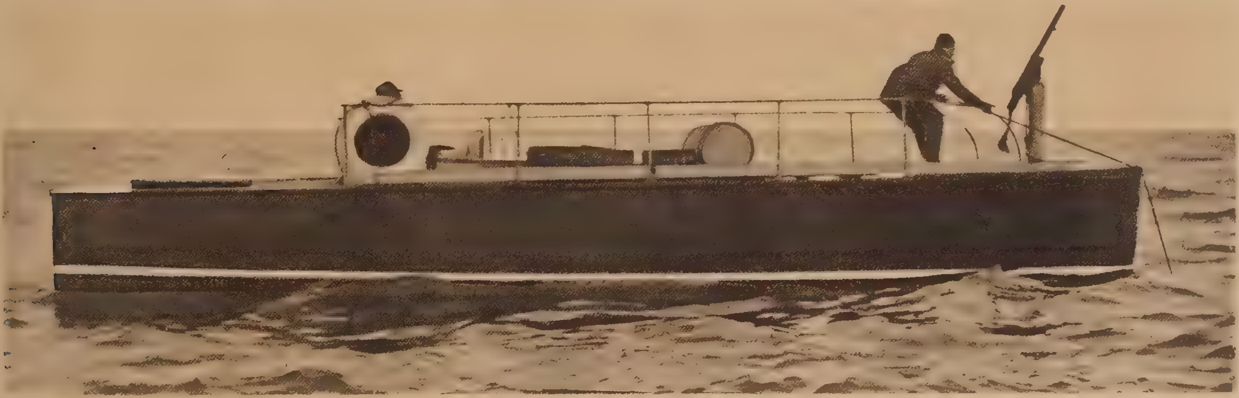

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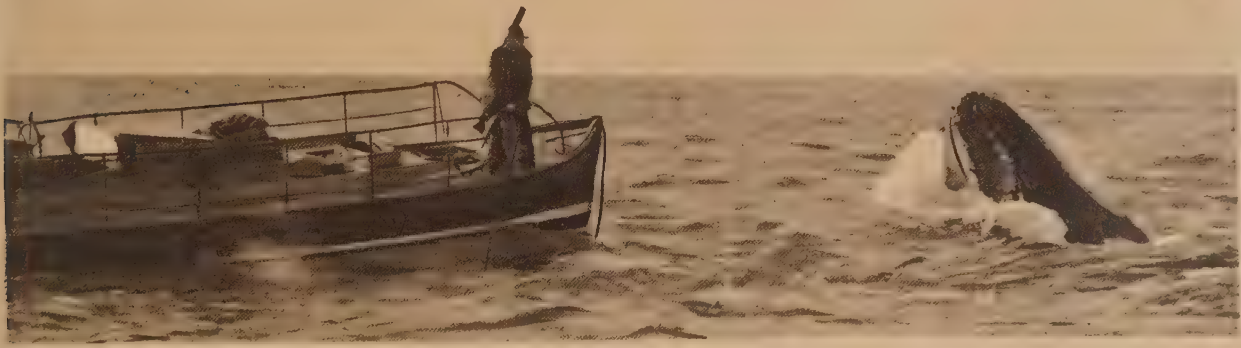

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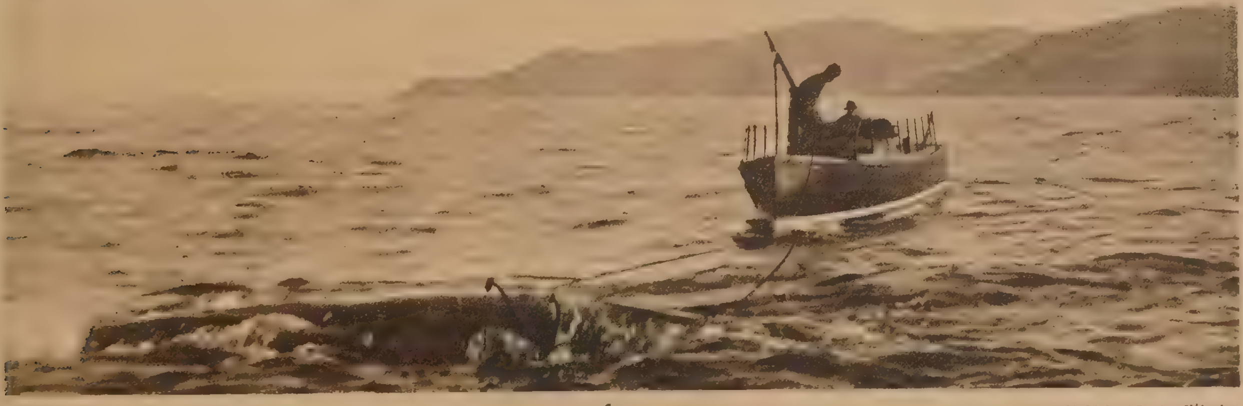

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NEW ZEALAND WHALING

PLATE XII

Fig. 1. A Humpback whale on the flensing slip at Whangamumu, Bay of Islands, New Zealand.

Fig. 2. The whaling station at Te-Awaiti, Tory Channel, with Humpback whale on the slip.

Fig. 3. Light harpoon gun used by the New Zealand whalers for the capture of Humpbacks with motor launches.

Fig. 4. Harpoon of the type used at the Te-Awaiti station. Note the slender shaft, curved barbs and triangular grenade at the head.

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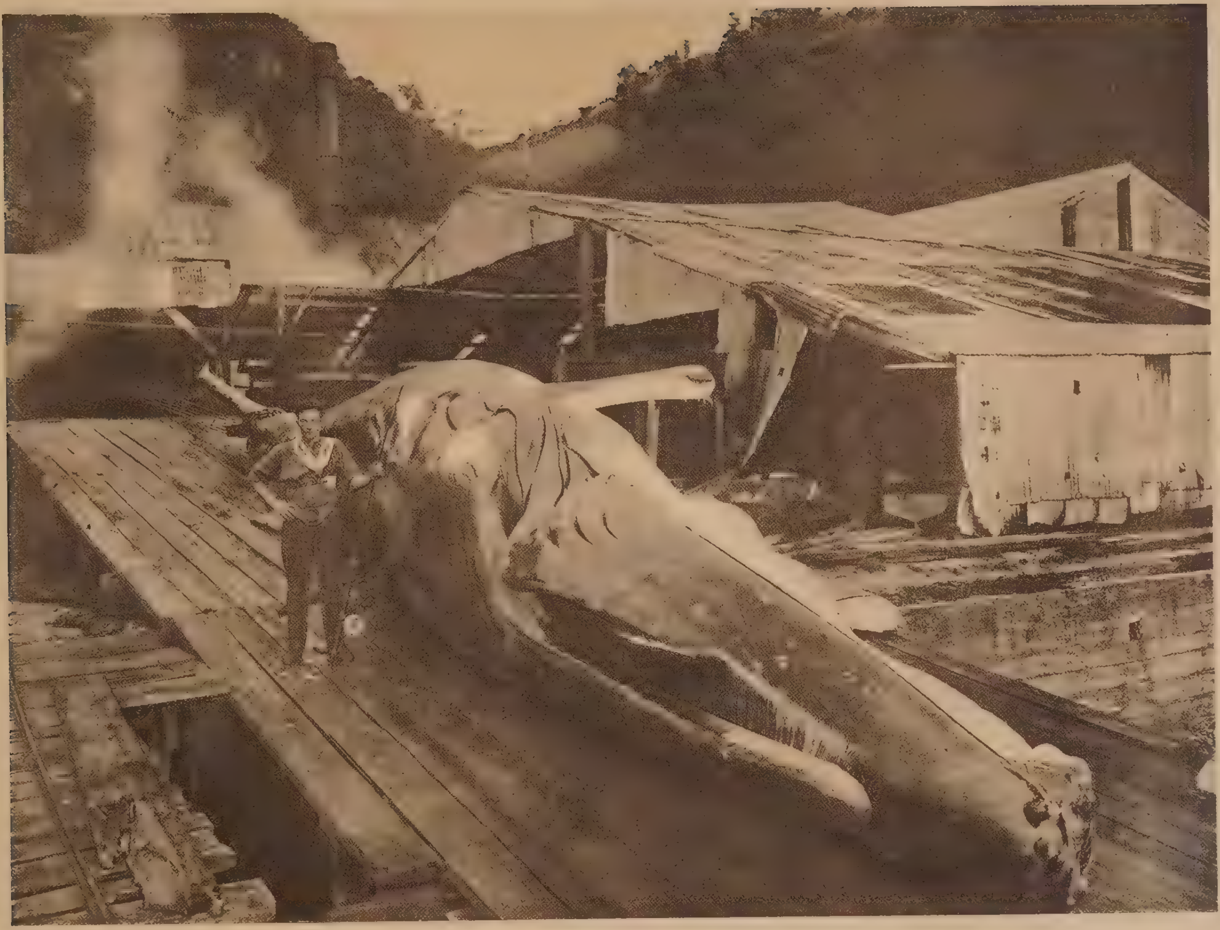

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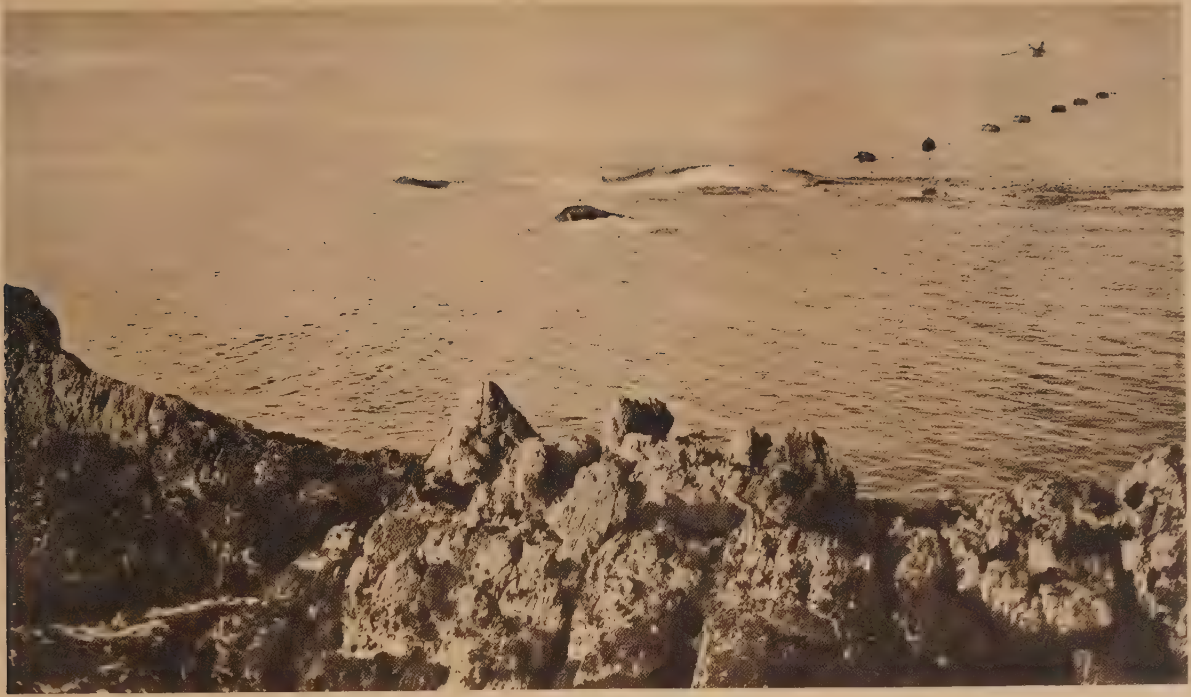
NEW ZEALAND WHALING

PLATE XIII

Fig. 1. Capture of Humpback whales by means of nets near Whangamumu, Bay of Islands. The nets are suspended from a cable attached to a line of buoys for a distance of 50–100 yards from the shore, as shown in the photograph, or suspended between rocks across a channel through which the whales are known to pass. The photograph, taken about 1900 by the late Josiah Martin, shows the wash of a whale which has become entangled in the net. The rowing boat is standing off in the distance with the harpooners. At the time when this photograph was taken hand harpoons were used.

Fig. 2. Two Humpback whales in the water at Whangamumu, Bay of Islands. This photograph, taken also by the late Josiah Martin about 1900, shows the old method of flensing the carcases in the water. The "shears" for manipulating the carcase in the water can be seen in the background. The blubber of the whale farthest from the camera is being cut into square sections.

From photographs lent to the author by Mr A. W. B. Powell.



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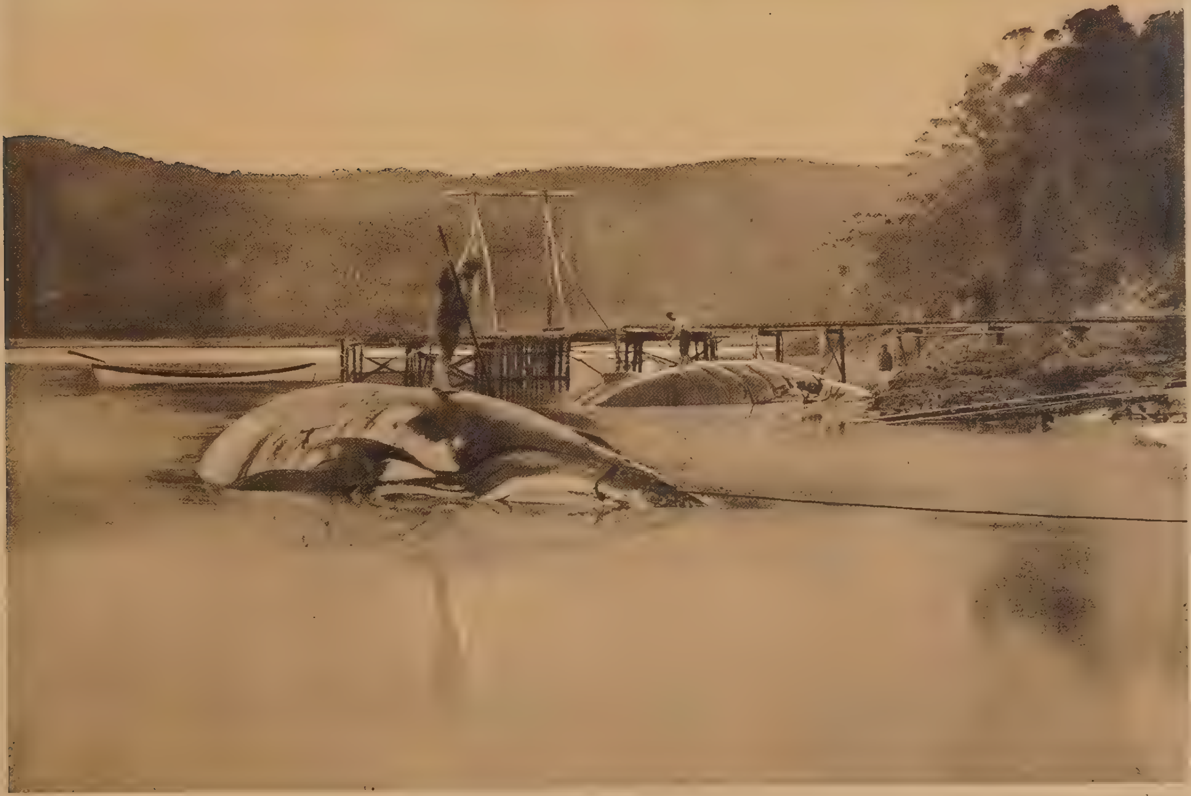

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NEW ZEALAND WHALING

[*Discovery Reports. Vol. VII, pp.* 253–362, *Plate XIV, December,* 1933]

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ISOPOD CRUSTACEA

PART I. THE FAMILY SEROLIDAE

By

EDITH M. SHEPPARD, M.Sc.

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ISOPOD CRUSTACEA

PART I. THE FAMILY SEROLIDAE

By Edith M. Sheppard, M.Sc.

(Plate XIV; text-figs. 1–22)

INTRODUCTION

THE present report is based on the collections of Serolids made by the R.R.S. 'Discovery', the R.R.S. 'Discovery II', the R.R.S. 'William Scoresby' and the staff of the Marine Biological Station at South Georgia during the years 1925–32. Most of the material was obtained from the shallow waters around South Georgia, the South Orkneys, the South Shetlands, the South Sandwich Islands, Palmer Archipelago, and the Falkland Islands, as well as off the coast of the southern part of South America and in the shallow waters between the latter and the Falkland Islands.

The present collection is undoubtedly the most complete ever made both with regard to the number of species as well as to the actual number of specimens procured. Of the fifteen shallow-water species (excluding the two doubtful ones, *Serolis serrei*, Lucas, and *S. plana*, Dana) previously recorded from these waters, all excepting three, *S. polaris*, Richardson, and *S. laevis*, Richardson, from the shores of the South Sandwich Islands, and *S. paradoxa*, Fabricius, from Patagonian waters, have again made their appearance, and to this number may be added a further seven, which are new to science. Perhaps the most striking feature of the collection is the extraordinary abundance, throughout the year, of the two species *S. schythei*, Lütken, and *S. exigua*, Nordenstam, both of which have been recorded from a large number of stations to the north and south of the Falkland Islands, as well as in the shallow waters between the islands and the mainland.

By kind permission of the Discovery Committee this report also contains a revised account of the genus *Serolis* with diagnostic characters of all the known species, together with notes on their geographical distribution and general morphology.

I wish to take this opportunity of thanking the Discovery Committee for entrusting me with the examination of this valuable collection. I also wish to thank Dr Calman for his helpful advice, and for the facilities he has given me for the examination of the specimens at the British Museum. My thanks are due also to Professor Ch. Gravier, of the Museum d'Histoire Naturelle, Paris, Dr P. H. Grimshaw, of the Royal Scottish Museum, Edinburgh, Dr Waldo Schmitt, of the U.S. National Museum, Washington, and Professor Dr von Straelen, Directeur du Musée Royal d'Histoire Naturelle de Belgique, who, by the loan of specimens, have enabled me to examine all except one (*S. bakeri*, Chilton) of the existing species of *Serolis*.

Lastly, I wish to express my deep gratitude to Professor W. M. Tattersall, University College, Cardiff, for his valuable advice and unfailing interest in the preparation of this report, as well as for the loan of numerous papers from his valuable carcinological library.

Since sending this paper to press, further zoological results of the Swedish Antarctic Expedition, 1901–3, have been published in a paper on "Marine Isopoda" by Nordenstam (1933). This contains a section on the family Serolidae and wherever necessary references to it have been inserted in the present paper.

LIST OF SPECIES

The genus *Serolis* contains thirty-seven species, excluding the two doubtful ones, *S. serrei*, Lucas, and *S. plana*, Dana, and nineteen of these, six of which are new to science, are represented in the present collection.

In the following list, species appearing in this collection are marked with an asterisk (*), other Antarctic Expeditions are indicated by the following letters: B = Belgica; C = Challenger; D = Discovery; F = Français; G = Gazelle; Ga = Gauss; P = Pourquoi Pas?; S = Scotia; and T = Terra Nova.

*1. *S. beddardi*, Calman.
2. *S. latifrons*, White. C, G, Ga.
3. *S. gracilis*, Beddard. C.
4. *S. paradoxa*, Fabricius. C, G.
*5. *S. schythei*, Lütken. C, G.
6. *S. polaris*, Richardson. F.
*7. *S. glacialis*, Tattersall. B, T.
*8. *S. septemcarinata*, Miers. C, G.
*9. *S. kempi*, n.sp.
*10. *S. polita*, Pfeffer. F, T.
*11. *S. elliptica*, n.sp.
*12. *S. exigua*, Nordenstam.
13. *S. carinata*, Lockington.
*14. *S. convexa*, Cunningham. C, G.
*15. *S. gaudichaudii*, Aud. et Edw. C.
16. *S. laevis*, Richardson. F.
17. *S. gerlachei*, Monod. B.
18. *S. meridionalis*, Hodgson. Ga, S.
*19. *S. cornuta*, Studer.
*20. *S. trilobitoides*, Eights. B, C, D, G, P.
21. *S. antarctica*, Beddard. C.
22. *S. bromleyana*, Suhm. C.
*23. *S. neaera*, Beddard. C.
24. *S. minuta*, Beddard. C.
25. *S. bakeri*, Chilton.
26. *S. yongei*, Hale.
*27. *S. orbiculata*, n.sp.
*28. *S. nototropis*, n.sp.
*29. *S. pagenstecheri*, Pfeffer. T.
*30. *S. platygaster*, n.sp.
*31. *S. bouvieri*, Richardson. F, P.
*32. *S. aspera*, n.sp.
33. *S. australiensis*, Beddard. C.
34. *S. elongata*, Beddard. C.
35. *S. longicaudata*, Beddard. C.
36. *S. tuberculata*, Grube. C.
37. *S. pallida*, Beddard. C.

LIST OF STATIONS

In the following list the stations made by the 'Discovery' and the 'Discovery II' have no letters prefixed to the numbers; those of the 'William Scoresby' have the prefix WS, and those of the Marine Biological Station MS. A considerable part of the material was obtained in fine nets of varying mesh attached to the back of the trawl, a method of great efficiency for the collection of Crustacea and other small invertebrates which live on the sea-floor.

St. 32. 17. iii. 26. South Georgia, 22·8 miles N 70½° E of Jason Light. 1 m. tow-net, 0–5 m.

S. septemcarinata, Miers.

St. 39. 25. iii. 26. South Georgia, East Cumberland Bay, from 8 cables S 81° W of Merton Rock to 1·3 miles N 7° E of Macmahon Rock. Trawl and attached nets, grey mud, 179–235 m.

S. pagenstecheri, Pfeffer; *S. aspera*, n.sp.; *S. septemcarinata*, Miers.

St. 42. 1. iv. 26. South Georgia, off mouth of Cumberland Bay, from 6·3 miles N 89° E to 4 miles N 39° E of Jason Light. Net attached to trawl, mud, 120–204 m.

S. pagenstecheri, Pfeffer.

St. 45. 6. iv. 26. South Georgia, 2·7 miles S 85° E of Jason Light. Net attached to trawl, grey mud, 238–270 m.

S. septemcarinata, Miers.

St. 51. 4. v. 26. East Falkland Islands, off Eddystone Rock, from 7 miles N 50° E to 7·6 miles N 63° E of Eddystone Rock. Large dredge, fine sand, 115 m.; nets attached to trawl, fine sand, 105–115 m.

S. schythei, Lütken; *S. convexa*, Cunningham; *S. exigua*, Nordenstam.

St. 56. 16. v. 26. East Falkland Islands, Sparrow Cove, Port William, 1½ cables N 50° E of Sparrow Point. Net attached to small trawl, 10½–16 m.

S. elliptica, n.sp.

St. 123. 15. xii. 26. South Georgia, off mouth of Cumberland Bay, from 4·1 miles N 54° E of Larsen Point to 1·2 miles S 62° W of Merton Rock. Net attached to trawl, grey mud, 230–250 m.

S. aspera, n.sp.

St. 140. 23. xii. 26. South Georgia, Stromness Harbour to Larsen Point, from 54° 02′ S, 36° 38′ W to 54° 11′ 30″ S, 36° 29′ W. Net attached to trawl, green mud and stones, 122–136 m.

S. pagenstecheri, Pfeffer; *S. aspera*, n.sp.

St. 144. 5. i. 27. South Georgia, off mouth of Stromness Harbour, from 54° 04′ S, 36° 27′ W to 53° 58′ S, 36° 26′ W. Net attached to trawl, green mud and sand, 155–178 m.

S. pagenstecheri, Pfeffer.

St. 146. 8. i. 27. 53° 48′ S, 35° 37′ 30″ W. Large dredge, rock, 728 m.

S. platygaster, n.sp.

St. 148. 9. i. 27. South Georgia, off Cape Saunders, from 54° 03′ S, 36° 39′ W to 54° 05′ S, 36° 36′ 30″ W. Net attached to trawl, grey mud and stones, 132–148 m.

S. aspera, n.sp.

St. 149. 10. i. 27. South Georgia, mouth of East Cumberland Bay, from 1·15 miles N 76½° W to 2·62 miles S 11° W of Merton Rock. Net attached to trawl, mud, 200–234 m.

S. pagenstecheri, Pfeffer.

St. 157. 20. i. 27. South Georgia, 53° 51′ S, 36° 11′ 15″ W. Large dredge, diatom ooze, stones, fine sand, 970 m.

S. pagenstecheri, Pfeffer.

St. 160. 7. ii. 27. Near Shag Rocks, 53° 43′ 40″ S, 40° 57′ W. Large dredge, grey mud, stones and rock, 177 m.

S. aspera, n.sp.

St. 164. 18. ii. 27. South Orkneys, east end of Normanna Strait, near Cape Hansen, Coronation Island. Small beam trawl, 24–36 m.

S. cornuta, Studer.

St. 170. 23. ii. 27. Clarence Island, off Cape Bowles, 61° 25′ 30″ S, 53° 46′ W. Large dredge, rock, 342 m.

S. trilobitoides, Eights.

St. 172. 26. ii. 27. South Shetlands, off Deception Island, 62° 59′ S, 60° 28′ W. Large dredge, rock, 525 m.

S. trilobitoides, Eights.

St. 174. 28. ii.–2. iii. 27. South Shetlands, Deception Island, outside entrance, W of Light. Large fish-trap, 5–10 m.

S. beddardi, Calman.

St. 180. 11. iii. 27. Palmer Archipelago, 1·7 miles W of N point of Gand Island, Schollaert Channel. Net attached to trawl, mud and stones, 160–330 m.

S. glacialis, Tattersall.

St. 181. 12. iii. 27. Palmer Archipelago, Schollaert Channel, 64° 20′ S, 63° 01′ W. Nets attached to trawl, mud, 160–335 m.

S. glacialis, Tattersall; *S. bouvieri*, Richardson.

St. 182. 14. iii. 27. Palmer Archipelago, Schollaert Channel, 64° 21′ S, 62° 58′ W. Nets attached to trawl, mud, 278–500 m.

S. glacialis, Tattersall.

St. 187. 18. iii. 27. Palmer Archipelago, Neumayr Channel, 64° 48′ 30″ S, 63° 31′ 30″ W. Large dredge, mud, 259 m.

S. glacialis, Tattersall.

St. 190. 24. iii. 27. Palmer Archipelago, Bismarck Strait, 64° 56′ S, 65° 35′ W.

(1) Large dredge and large rectangular net, rock, stones and mud, 93–130 m.

S. bouvieri, Richardson.

(2) Large dredge, mud and rock, 315 m.

S. bouvieri, Richardson.

St. 195. 30. iii. 27. South Shetlands, Admiralty Bay, King George Island, 62° 07′ S, 58° 28′ 30″ W. Nets attached to trawl, mud and stones, 391 m.

S. bouvieri, Richardson.

St. 223. 27. iv. 27. Cape Horn, St Francis' Bay, 55° 51′ 15″ S, 67° 29′ 30″ W. Large rectangular net, sand, 63 m.

S. schythei, Lütken.

St. 363. 26. ii. 30. South Sandwich Islands, 2·5 miles S 80° E of SE point of Zavodovski Island. Large dredge, 329–278 m.

S. cornuta, Studer.

St. 371. 14. iii. 30. South Sandwich Islands, 1 mile E of Montagu Island. Net attached to trawl 99–161 m.

S. polita, Pfeffer.

St. 388. 16. iv. 30. 56° 19½′ S, 67° 09¾′ W. Large dredge, 121 m.

S. kempi, n.sp.

St. 456. 18. x. 30. 1 mile E of Bouvet Island. Large dredge, 40–45 m.

S. septemcarinata, Miers.

St. WS 25. 17. xii. 26. South Georgia, Undine Harbour (North). Small beam trawl, mud, sand, 18–27 m.

S. polita, Pfeffer.

St. WS 62. 19. i. 27. South Georgia, Wilson Harbour. Small beam trawl, 26–83 m.
S. pagenstecheri, Pfeffer.

St. WS 72. 5. iii. 27. 51° 07′ S, 57° 34′ W. Net attached to trawl, sand, shells, 79 m.
S. schythei, Lütken.

St. WS 73. 6. iii. 27. 51° 01′ S, 58° 54′ W. Nets attached to trawl, fine dark sand, 121–130 m.
S. schythei, Lütken.

St. WS 75. 10. iii. 27. 51° 01′ 30″ S, 60° 31′ W. Trawl, 72 m.
S. schythei, Lütken; *S. convexa*, Cunningham.

St. WS 76. 11. iii. 27. 51° 00′ S, 62° 02′ 30″ W. Trawl, fine dark sand, 207–205 m.
S. schythei, Lütken.

St. WS 78. 13. iii. 27. 51° 01′ S, 68° 04′ 30″ W, from 51° 01′ S, 68° 02′ W to 51° 01′ S, 68° 07′ W. Net attached to trawl, fine dark sand, 91–95 m.
S. schythei, Lütken.

St. WS 79. 13. iii. 27. 51° 01′ 30″ S, 64° 59′ 30″ W. Net attached to trawl, fine dark sand, 132 m.
S. schythei, Lütken.

St. WS 80. 14. iii. 27. 50° 57′ S, 63° 37′ 30″ W. Trawl and attached nets, fine dark sand, 152–156 m.
S. exigua, Nordenstam; *S. schythei*, Lütken.

St. WS 83. 24. iii. 27. 14 miles S 64° W of George Island, East Falkland Islands. Net attached to trawl, fine green sand and shells, 137–129 m.
S. schythei, Lütken.

St. WS 86. 3. iv. 27. 53° 53′ 30″ S, 60° 34′ 30″ W. Net attached to trawl, sand, shells and stones, 151–147 m.
S. kempi, n.sp.

St. WS 90. 7. iv. 27. 13 miles N 83° E of Cape Virgins Light, Argentine Republic. Net attached to trawl, fine dark sand, 82–81 m.
S. schythei, Lütken; *S. convexa*, Cunningham.

St. WS 210. 29. v. 28. 50° 17′ S, 60° 06′ W. Net attached to trawl, green sand, 161 m.
S. schythei, Lütken; *S. exigua*, Nordenstam.

St. WS 211. 29. v. 28. 50° 17′ S, 60° 06′ W. Net attached to trawl, green sand, 174 m.
S. schythei, Lütken.

St. WS 212. 30. v. 28. 49° 22′ S, 60° 10′ W. Nets attached to trawl, green sand, mud and pebbles, 242–249 m.
S. exigua, Nordenstam; *S. neaera*, Beddard.

St. WS 213. 30. v. 28. 49° 22′ S, 60° 10′ W. Net attached to trawl, green sand, mud and pebbles, 249–239 m.
S. neaera, Beddard.

St. WS 214. 31. v. 28. 48° 25′ S, 60° 40′ W. Nets attached to trawl, fine dark sand, 208–219 m.
S. exigua, Nordenstam; *S. schythei*, Lütken.

St. WS 215. 31. v. 28. 47° 37′ S, 60° 50′ W. Net attached to trawl, fine green sand, 219–146 m.
S. schythei, Lütken; *S. exigua*, Nordenstam.

St. WS 216. 1. vi. 28. 47° 37′ S, 60° 50′ W. Net attached to trawl, fine sand, 219–133 m.

S. schythei, Lütken; *S. exigua*, Nordenstam.

St. WS 219. 3. vi. 28. 47° 06′ S, 62° 12′ W. Net attached to trawl, dark sand, 116–114 m.

S. schythei, Lütken; *S. exigua*, Nordenstam.

St. WS 220. 3. vi. 28. 47° 56′ S, 62° 38′ W. Net attached to trawl, brown sand, 108–104 m.

S. exigua, Nordenstam; *S. convexa*, Cunningham.

St. WS 221. 4. vi. 28. 48° 23′ S, 65° 10′ W. Net attached to trawl, brown sand and mud, pebbles, large stones and shells, 76–91 m.

S. exigua, Nordenstam; *S. gaudichaudii*, Aud. et Edw.

St. WS 222. 8. vi. 28. 48° 23′ S, 65° W. Net attached to trawl, coarse brown sand and shells, 100–106 m.

S. exigua, Nordenstam; *S. orbiculata*, n.sp.; *S. convexa*, Cunningham.

St. WS 225. 9. vi. 28. 50° 20′ S, 62° 30′ W. Net attached to trawl, green sand, shells and pebbles, 162–161 m.

S. exigua, Nordenstam; *S. schythei*, Lütken.

St. WS 226. 10. vi. 28. 49° 20′ S, 62° 30′ W. Net attached to trawl, green sand, 144–152 m.

S. schythei, Lütken.

St. WS 227. 12. vi. 28. 51° 08′ S, 56° 50′ W. Net attached to trawl, fine green sand, 295 m.

S. exigua, Nordenstam.

St. WS 228. 30. vi. 28. 50° 50′ S, 56° 58′ W. Nets attached to trawl, shells and coarse white sand, 229–236 m.

S. exigua, Nordenstam.

St. WS 229. 1. vii. 28. 50° 35′ S, 57° 20′ W. Net attached to trawl, fine green sand, 210–271 m.

S. exigua, Nordenstam; *S. schythei*, Lütken.

St. WS 231. 4. vii. 28. 50° 10′ S, 58° 42′ W. Net attached to trawl, fine green sand, 167–159 m.

S. exigua, Nordenstam.

St. WS 233. 5. vii. 28. 49° 25′ S, 59° 45′ W. Net attached to trawl, fine green sand, 185–175 m.

S. exigua, Nordenstam; *S. schythei*, Lütken.

St. WS 234. 5. vii. 28. 48° 52′ S, 60° 25′ W. Net attached to trawl, fine green sand, 195–207 m.

S. exigua, Nordenstam; *S. schythei*, Lütken.

St. WS 235. 6. vii. 28. 47° 56′ S, 61° 10′ W. Net attached to trawl, dark green sand, 155–155 m.

S. schythei, Lütken.

St. WS 236. 6. vii. 28. 46° 55′ S, 60° 40′ W. Net attached to trawl, dark green sand and mud, 273–300 m.

S. exigua, Nordenstam; *S. neaera*, Beddard; *S. schythei*, Lütken.

St. WS 237. 7. vii. 28. 46° 00′ S, 60° 05′ W. Nets attached to trawl, coarse brown sand and shells, 150–256 m.

S. schythei, Lütken; *S. exigua*, Nordenstam.

St. WS 239. 15. vii. 28. 51° 10′ S, 62° 10′ W. Net attached to trawl, coarse dark sand, 196–192 m.

S. schythei, Lütken.

St. WS 243. 17. vii. 28. 51° 06′ S, 64° 30′ W. Net attached to trawl, coarse dark sand, 144–141 m.

S. exigua, Nordenstam; *S. elliptica*, n.sp.; *S. schythei*, Lütken.

St. WS 244. 18. vii. 28. 52° 00′ S, 62° 40′ W. Net attached to trawl, fine dark sand and mud, 253–248 m.

S. schythei, Lütken; *S. neaera*, Beddard; *S. kempi*, n.sp.

St. WS 245. 18. vii. 28. 52° 36′ S, 63° 40′ W. Net attached to trawl, dark green sand, madrepore sand, pebbles and shells, 304–290 m.

S. kempi, n.sp.; *S. schythei*, Lütken.

St. WS 246. 19. vii. 28. 52° 25′ S, 61° 00′ W. Nets attached to trawl, coarse green sand and pebbles, 267–208 m.

S. kempi, n.sp.; *S. exigua*, Nordenstam.

St. WS 742. 5. ix. 31. 38° 22′ S, 73° 41′ W. Small beam trawl, 47–35 m.

S. gaudichaudii, Aud. et Edw.

St. WS 752. 19–20. ix. 31. 51° 20′ S, 63° 17′ W. Rectangular net, 160 m.

S. schythei, Lütken.

St. WS 754. 20. ix. 31. 51° 09′ 30″ S, 58° 54′ W. Rectangular net, 106 m.

S. schythei, Lütken.

St. WS 758. 12. x. 31. 48° 32′ S, 61° 19′ W. Rectangular net, rock, 112 m.

S. schythei, Lütken.

St. WS 763. 16. x. 31. 44° 14′ S, 63° 28′ W. Net attached to trawl, mud and sand, 87–82 m.

S. schythei, Lütken.

St. WS 765. 17. x. 31. 45° 07′ S, 60° 28′ 15″ W. Trawl, brown and green mud and sand, 113–118 m.

S. schythei, Lütken.

St. WS 766. 18–19. x. 31. 45° 13′ S, 59° 56′ 30″ W. Net attached to trawl, fine dark grey sand, 545 m.

S. exigua, Nordenstam.

St. WS 771. 29. x. 31. 42° 41′ 45″ S, 60° 31′ W. Trawl, dark green sand, 90 m.

S. schythei, Lütken.

St. WS 772. 31. x. 31. 47° 28′ S, 60° 51′ W. Nets attached to trawl, grey sand, 309–162 m.

S. schythei, Lütken.

St. WS 773. 31. x. 31. 47° 28′ S, 60° 51′ W. Net attached to trawl, green sand and mud, 291–296 m.

S. neaera, Beddard; *S. exigua*, Nordenstam.

St. WS 774. 1. xi. 31. 47° 08′ S, 62° 02′ W. Net attached to trawl, dark green sand and mud, 139–144 m.

S. schythei, Lütken.

St. WS 775. 2. xi. 31. 46° 44′ 45″ S, 63° 33′ W. Nets attached to trawl, gravel and fine grey sand, 115–110 m.

S. schythei, Lütken.

St. WS 776. 3. xi. 31. 46° 18′ 15″ S, 65° 02′ 15″ W. Net attached to trawl, green mud and sand, 107–99 m.

S. schythei, Lütken.

St. WS 781. 6. xi. 31. 50° 30′ S, 58° 50′ W. Net attached to trawl, dark green sand and mud, 148 m.

S. exigua, Nordenstam; *S. schythei*, Lütken.

St. WS 782. 4. xii. 31. 50° 29′ 15″ S, 58° 23′ 45″ W. Net attached to trawl, green sand, 141 m.

S. exigua, Nordenstam; *S. schythei*, Lütken.

St. WS 783. 5. xii. 31. 50° 02′ 45″ S, 60° 14′ W. Net attached to trawl, rock, mud and sand, 159–0 m.

S. schythei, Lütken.

St. WS 786. 7. xii. 31. 49° 07′ S, 63° 55′ W. Net attached to trawl, dark sand, 133–119 m.

S. schythei, Lütken; *S. exigua*, Nordenstam.

St. WS 787. 7. xii. 31. 48° 44′ S, 65° 24′ 30″ W. Net attached to trawl, coarse brown sand, 106–110 m.

S. exigua Nordenstam; *S. schythei*, Lütken; *S. convexa*, Cunningham.

St. WS 791. 14. xii. 31. 45° 41′ 45″ S, 62° 45′ W. Net attached to trawl, 96–101 m.

S. schythei, Lütken.

St. WS 796. 19. xii. 31. 47° 49′ 37″ S, 63° 42′ 30″ W. Net attached to trawl, coarse brown sand, 106–113 m.

S. nototropis, n.sp.; *S. convexa*, Cunningham; *S. exigua*, Nordenstam.

St. WS 797. 19. xii. 31. 47° 45′ 36″ S, 64° 20′ W. Net attached to trawl, 115–111 m.

S. nototropis, n.sp.; *S. convexa*, Cunningham; *S. schythei*, Lütken.

St. WS 801. 22. xii. 31. 48° 26′ 15″ S, 61° 28′ W. Net attached to trawl, dark sand, 165 m.

S. exigua, Nordenstam.

St. WS 802. 5. i. 32. 50° 45′ 45″ S, 61° 22′ W. Net attached to trawl, 128–132 m.

S. schythei, Lütken; *S. exigua*, Nordenstam.

St. WS 802. 5. i. 32. 50° 43′ 45″ S, 61° 26′ W. Net attached to trawl, 132–139 m.

S. schythei, Lütken.

St. WS 804. 6. i. 32. 50° 21′ 15″ S, 62° 53′ W. Net attached to trawl, gravel and sand, 143–150 m.

S. exigua, Nordenstam.

St. WS 805. 6. i. 32. 50° 10′ 15″ S, 63° 29′ W. Net attached to trawl, coarse dark sand, 148 m.

S. exigua, Nordenstam.

St. WS 806. 7. i. 32. 50° 03′ 30″ S, 64° 21′ W. Net attached to trawl, 129–122 m.

S. exigua, Nordenstam.

St. WS 808. 8. i. 32. 49° 28′ 15″ S, 65° 42′ W. Net attached to trawl, brown and green sand, 109–107 m.

S. exigua, Nordenstam; *S. orbiculata*, n.sp.; *S. convexa*, Cunningham.

St. WS 809. 8. i. 32. 49° 28′ 15″ S, 66° 29′ W. Net attached to trawl, brown sand, 107–104 m.

S. gaudichaudii, Aud. et Edw.; *S. orbiculata*, n.sp.

St. WS 811. 12. i. 32. 51° 24′ 30″ S, 67° 53′ W. Net attached to trawl, 96–98 m.

S. convexa, Cunningham.

St. WS 813. 13. i. 32. 51° 35′ 15″ S, 67° 16′ 15″ W. Net attached to trawl, dark sand, 106 m.

S. nototropis, n.sp.; *S. exigua*, Nordenstam; *S. convexa*, Cunningham; *S. orbiculata*, n.sp.

St. WS 814. 13. i. 32. 51° 45′ 15″ S, 66° 40′ W. Net attached to trawl, 111–118 m.

S. exigua, Nordenstam; *S. schythei*, Lütken; *S. convexa*, Cunningham.

St. WS 815. 13. i. 32. 51° 51′ 45″ S, 65° 44′ W. Net attached to trawl, 132–162 m.

S. nototropis, n.sp.; *S. exigua*, Nordenstam; *S. convexa*, Cunningham; *S. orbiculata*, n.sp. *S. schythei*, Lütken.

St. WS 816. 14. i. 32. 52° 09′ 45″ S, 64° 56′ W. Net attached to trawl, sand, 150 m.

S. nototropis, n.sp.; *S. exigua*, Nordenstam; *S. schythei*, Lütken.

St. WS 818. 17. i. 32. 52° 31′ 15″ S, 63° 25′ W. Net attached to trawl, dark sand, 272–278 m.

S. schythei, Lütken; *S. kempi*, n.sp.; *S. exigua*, Nordenstam.

St. WS 820. 18. i. 32. 52° 53′ 15″ S, 61° 51′ W. Net attached to trawl, fine dark sand and mud, 351–367 m.

S. neaera, Beddard.

St. WS 821. 18. i. 32. 52° 55′ 45″ S, 60° 55′ W. Net attached to trawl, green and grey fine sand and mud, 461–468 m.

S. neaera, Beddard; *S. exigua*, Nordenstam.

St. WS 824. 19. i. 32. 52° 29′ 15″ S, 58° 27′ 15″ W. Net attached to trawl, green sand and shells, 146–137 m.

S. schythei, Lütken.

St. WS 825. 28–29. i. 32. 50° 50′ S, 57° 15′ 15″ W. Net attached to trawl, green sand, mud and shells, 135–144 m.

S. schythei, Lütken; *S. exigua*, Nordenstam.

St. WS 837. 3. ii. 32. 52° 49′ 15″ S, 66° 28′ W. Net attached to trawl, coarse, dark green sand and pebbles, 98–102 m.

S. nototropis, n.sp.; *S. exigua*, Nordenstam.

St. WS 839. 5. ii. 32. 53° 30′ 15″ S, 63° 29′ W. Net attached to trawl, fine sand and mud, 403–434 m.

S. neaera, Beddard.

St. WS 856. 23. iii. 32. 46° 45′ S, 64° 11′ W. Small beam trawl, 104 m.

S. gaudichaudii, Aud. et Edw.

St. WS 864. 28. iii. 32. 49° 33′ 30″ S, 64° 16′ W. Net attached to trawl, 128–126 m.

S. exigua, Nordenstam.

St. WS 866. 29. iii. 32. 50° 37′ 45″ S, 64° 15′ W. Net attached to trawl, 137–144 m.

S. exigua, Nordenstam; *S. schythei*, Lütken.

St. MS 10. 14. ii. 25. East Cumberland Bay, ¼ mile SE of Hope Point to ¼ mile S of Government Flagstaff. Small beam trawl, 26 m.

S. pagenstecheri, Pfeffer.

St. MS 65. 28. ii. 25. East Cumberland Bay, 1·6 miles SE of Hobart Rock to 1 cable N of Dartmouth Point. Net attached to small beam trawl, 18 m.

S. polita, Pfeffer.

St. MS 66. 28. ii. 25. East Cumberland Bay, 2¼ miles SE of King Edward Point Light to 1½ cables W × N of Macmahon Rock. Small beam trawl, 18 m.

S. polita, Pfeffer.

St MS 67. 28. ii. 25. East Cumberland Bay, 3 cables NE of Hobart Rock to ½ cable W of Hope Point. Small beam trawl, 38 m.

S. polita, Pfeffer; *S. pagenstecheri*, Pfeffer.

St. MS 71. 9. iii. 26. East Cumberland Bay, 9¼ cables E × S to 1·2 miles E × S of Sappho Point. Small beam trawl, 110–60 m.

S. septemcarinata, Miers.

GEOGRAPHICAL DISTRIBUTION

The geographical range of the genus *Serolis*, with the exception of *S. carinata*, Lockington, which is recorded as far north as San Diego, California, is entirely restricted to the southern hemisphere.

In the following account the distribution of the species has been considered with reference to the Antarctic Convergence. At this line, which surrounds the Antarctic Continent, there is an abrupt change in salinity and temperature, and it has been found that in some groups of animals (e.g. fishes) there are two distinct faunas, one on either side of it. The line lies roughly midway between Cape Horn and Graham Land in the west, and passes north of the Shag Rocks and South Georgia, then eastward, crossing latitude 50° S at 20° E, passing a little south of Marion Island and the Crozet Islands and then through the middle of Kerguelen. The temperature along this line ranges from 0·50° to 3·0° in the winter to 3·50° to 5·50° in the summer. The majority of species of *Serolis* are confined to shallow waters; the deep-sea forms are comparatively few in number and have a much wider vertical as well as horizontal distribution.

According to Beddard (1884*b*, p. 82) "the shallow-water forms never pass the 300-fathom limit, nor are any of the deep-sea species known to inhabit shallow water". The study of accumulated data proves that this statement is no longer accurate, for at least two shallow-water forms are now known to inhabit depths greater than 300 fathoms. *S. pagenstecheri*, Pfeffer, is found in depths ranging from 15 to 970 m. (approximately 530 fathoms), and the new species, *S. platygaster*, which from its general characters is more closely related to the shallow-water species, was collected at a depth of 728 m. (approximately 393 fathoms). Further, *S. neaera*, Beddard, one of the deep-sea species, previously recorded from depths ranging from 600 to 2040 fathoms, is now known to exist in comparatively shallow waters: specimens in this collection occur at depths of 239–300 m. (approximately 130–164 fathoms).

The shallow-water species fall into four groups:

(1) Those which are found *outside* the Antarctic Convergence, off the coasts of the

southern part of South America, and on the shores of the Falkland Islands, as well as in the comparatively shallow waters between the two.

To this group belong the species *S. paradoxa*, Fabricius, *S. schythei*, Lütken, *S. convexa*, Cunningham, *S. gaudichaudii*, Aud. et Edw., *S. exigua*, Nordenstam, the new species *S. kempi*, *S. orbiculata*, *S. nototropis* and *S. elliptica*, and the two doubtful species *S. plana*, Dana, and *S. serrei*, Lucas. Of these *S. gaudichaudii* extends farther north than the rest, the original specimen having been collected near Valparaiso.

Miers in his list of New Zealand Crustacea includes *S. paradoxa*, apparently (as Beddard, 1884*b*, p. 80, points out) "on the authority of a specimen at the British Museum", and the same collection of Crustacea contains a single example of a species which Beddard identifies as *S. schythei*, which is also labelled "New Zealand". Beddard continues: "I believe the locality is not authenticated beyond a doubt". With the exception of these two specimens, the species of this group so far collected are restricted to the above-mentioned localities.

(2) Those which occur *within* the Antarctic Convergence, on the shores of the South Sandwich Islands, South Georgia, the South Shetlands and the Palmer Archipelago, as well as off Coats Land (long. 20° W) and Oates Land (long. 155° E).

To this group belong *S. beddardi*, Calman, *S. glacialis*, Tattersall, *S. gerlachei*, Monod, *S. bouvieri*, Richardson, *S. polita*, Pfeffer, *S. pagenstecheri*, Pfeffer, *S. polaris*, Richardson, *S. laevis*, Richardson, *S. cornuta*, Studer, *S. trilobitoides*, Eights, *S. septemcarinata*, Miers, and the two new species, *S. aspera* and *S. platygaster*.

In Beddard's description of *S. cornuta* (1884*b*, pp. 52 and 53: *S. trilobitoides* of this paper), an error occurs in the list of stations at which the species was collected. The longitude in each case is given as west of Greenwich, with the result that the given stations lie within the Continent of South America. The actual stations are situated around the shores of Kerguelen in corresponding longitudes east of Greenwich. With the exception of a record of doubtful value (that of a specimen of *S. trilobitoides* described by Eights from the stomach of a fish collected in Patagonian waters), the species found within the Antarctic Convergence are all different from those present in the South American–Falkland Islands area.

(3) Those species which are found around the shores of Kerguelen Island, Crozet Island, Marion Island, and Prince Edward Island. These localities with the exception of Kerguelen, lie north of the convergence, considerably farther east than either of the localities referred to in groups (1) and (2) above. Kerguelen Island actually lies on the convergence, its southern shores being within it.

With the exception of *S. latifrons*, White, which is also recorded from Auckland Island, New Zealand, the species belonging to this group—namely, *S. cornuta*, Studer, *S. trilobitoides*, Eights, and *S. septemcarinata*, Miers—are also members of group (2) above.

(4) This group contains the species which are found off the shores of South and East Australia. These are: *S. australiensis*, Beddard, *S. bakeri*, Chilton, *S. minuta*, Beddard, *S. elongata*, Beddard, *S. tuberculata*, Grube, *S. longicaudata*, Beddard, *S. pallida*, Beddard, and *S. yongei*, Hale, from the Barrier Reef.

The marked difference in the shallow-water faunas of the two areas represented in groups (1) and (2) is not surprising considering that they are separated from each other not only by the sudden hydrographical change represented by the Antarctic Convergence but also by Drake Strait. This channel of water, which reaches a depth of over 2000 fathoms, may prove to be a barrier of even greater importance than the convergence to the bottom-living forms. It is interesting to note that this difference in the shallow-water faunas of these two areas has been noted by other investigators. Barnard, for example, states that the species of Amphipods in the two areas are entirely different.

An examination of the geological history of the area shows that, during Eocene times, the South Polar Continent, Antarctica, was united on the one hand with South America through Graham Land, and on the other with Australia. It is probable that the genus *Serolis* was already represented in the shallow-water fauna of the northern coast of this southern land-mass, and that its centre of distribution lay in the waters off the shores of Graham Land. This seat of origin would account for the northward spread of the genus and the almost entire absence of species from the shores of the west coast of South America.

During the Older Quaternary period, Australia broke away from the main southern continent, and this resulted in the isolation of certain species of *Serolis*, the further modification of which may be seen in the species of Australia to-day (group (4) above). It is significant that the existing species are found off the coast of South-east Australia in a region which was the last to lose its connection with the southern continent.

In the course of time, the formation and gradual deepening of the channel between South America and Graham Land would be sufficient to account for the separation of, and variation in, the species found in the shallow waters represented by the areas in groups (1) and (2) above.

It is possible that the presence of the same species in the two localities represented by groups (2) and (3), may be accounted for by the fact that conditions of life are much the same in the two areas. As already mentioned, the southern shores of Kerguelen lie within the convergence, and Marion Island, and Crozet Island, are respectively 120 and 160 miles north of it. According to information supplied to me by Mr G. E. R. Deacon of the Discovery scientific staff, the two latter islands are so close to the convergence that upwelling, which must take place somewhere near them, will bring to the surface Antarctic water which has not been below a depth of 200–300 m. St. 42, in 47° 53′ S, 61° 25′ E, and St. 43 in 47° 53′ S, 66° 26′ E, of the Gauss Expedition, are both north of the convergence. The former, 200 miles north, has Antarctic water at a depth of about 400–600 m.; the latter, 100 miles north, at a depth of 200–300 m. From these data it seems quite probable that the shallow water off the shores of these islands is partly of Antarctic origin, in which case the presence of similar species in the groups (2) and (3) above is made possible.

The distribution of the various species mentioned by Nordenstam (1933), with the exceptions of those occurring at stations 33 and 34 *b*, agrees with the grouping of species as shown above.

St. 33 of Nordenstam's paper is given as South Georgia, and at this station the three species *S. paradoxa*, *S. schythei* and *S. convexa* were collected: this is the only reference to the presence of these species *within* the Antarctic Convergence either in Nordenstam's or any other paper. Their distribution is *outside* the convergence, off the coasts of the southern part of South America and on the shores of the Falkland Islands as well as in the comparatively shallow waters between the two.

The locality of St. 34 *b* is given as "Atlantic Ocean, North of Falkland Islands and East of Patagonia, lat. 44° 19′ S., long. 57° 34′ W." and at this station *S. polita* and *S. septemcarinata* were collected; two species which occur otherwise either *within* the convergence or, in the case of *S. septemcarinata*, around the shores of Kerguelen Island as well.

It is possible that the labels referring to the material collected at these two stations have been interchanged, since the three species collected at St. 33 are characteristic of the locality represented by St. 34 *b*, and the two species collected at the latter station are characteristic of the locality represented by St. 33. This view is supported by the fact that at neither station were species characteristic of that locality collected, and, further, by the facts that both these areas have been extensively explored and that, in the numerous records, the distribution of the species has been so remarkably consistent.

CLASSIFICATION

ISOPODA, Latreille

FLABELLIFERA, Sars

Family SEROLIDAE

The family Serolidae, together with the families Anthuridae, Cymothoidae and Sphaeromidae, is included in the sub-order Flabellifera, Sars; it is perhaps more closely allied to the Sphaeromidae than to either of the other families. There are, however, fundamental differences between the members of the two families, for in the Serolidae the first and second thoracic somites are fused with the head, and the tergum of the eighth thoracic somite is usually absent and when present is never complete. In the Sphaeromidae only the first thoracic somite is fused with the head, and the remaining seven somites are all free and complete.

The family Serolidae contains the single genus *Serolis*, Leach, consequently the following definition will serve equally well for the family.

Genus Serolis, Leach

Oniscus, Fabricius, 1787, p. 240.
Asellus, Olivier, p. 252.
Cymothoa, Fabricius, 1793, p. 503.
Serolis, Leach, 1825, p. 340.
Brongiartia, Eights, 1833, p. 53.

An historical account of this genus is included in Beddard's report (1884 *b*, pp. 2–4), and for this reason I shall not refer to its earlier history.

The characters of the genus may be defined in the following terms:

Body depressed, flattened and usually broad, with the first two thoracic somites fused with the head, the sides of which are fused with the forward lateral extensions of the second somite; the tergum and coxal plates of the last (eighth) thoracic somite never complete, usually wanting; the tergum of the seventh thoracic somite may also be incomplete. Coxal plates of the first three free thoracic (3rd–5th) somites always separated from them by sutures; sometimes, in addition, those of the fourth, or those of all the remaining somites are also separated from them by sutures. First abdominal segment without pleural plates, sometimes partially fused with the tergum of the seventh thoracic somite; second and third abdominal segments free, with either short or long pleural plates; last two fused with telson to form a large terminal segment. Mouth-parts normal; antennule with four and antenna with five peduncular joints; each with a multi-articulate flagellum. Second pair of thoracic appendages of both sexes and third pair of adult male modified into a prehensile organ, the dactylus folding back upon the greatly dilated propodus; last thoracic appendage usually smaller than the others, and sometimes modified in the adult male. First three pairs of pleopods natatory, consisting of protopodite, exopod and endopod, the two latter fringed with long plumose setae; endopod of male prolonged into a long penial filament; fourth and fifth pleopods branchial. Uropods lateral in position, lamellar and usually biramous.

Calman (1920, p. 299), in his paper on the new species *S. beddardi*, suggested that it might form a distinct genus with the allied species *S. latifrons*, Miers, and further that a regrouping of the remaining species might be advisable. In his suggested classification which is based on the form of the uropods and of the terga of the posterior thoracic somites, he divides the species into three groups:

(i) A group containing *S. latifrons* and *S. beddardi*, in which the endopod of the uropod is absent, and the tergum of the last (eighth) thoracic somite persists as a pair of minute lateral sclerites each with a coxal plate separated by a suture. In both the remaining groups the uropod bears an exopod and an endopod.

(ii) A group containing the six Australian species, *S. tuberculata*, Grube, *S. australiensis*, Beddard, *S. longicaudata*, Beddard, *S. elongata*, Beddard, *S. minuta*, Beddard, and *S. pallida*, Beddard, which Beddard (1884 *b*, pp. 66 and 81) states form "a well-marked subdivision of the genus", together with *S. bakeri*, Chilton.

(iii) A group, represented by *S. paradoxa*, Fabricius, containing all the remaining species.

The following points result from a consideration of these groups as they stand:

(1) That the absence of the endopod of the uropod is a character which is no longer peculiar to the members of group (i). It is absent from the uropod of *S. platygaster*, n.sp., a species which is in no other way closely related to members of this group.

(2) That if this character (absence of endopod) is disregarded the only character separating members of this group from those of group (iii) is the presence of small

lateral portions of the tergum of the last thoracic somite, with its corresponding coxal plates.

(3) That group (iii), containing the remaining species, includes *S. pagenstecheri*, Pfeffer, in which the tergum of the seventh thoracic somite is fused with that of the first abdominal segment for a short distance on either side of the mid-dorsal line. Consequently members of the "Australian group" do not bear characters which distinguish them from all the remaining species.

(4) That group (ii), containing the Australian species, is itself by no means a uniform group and should be divided into three:

(*a*) A group to contain those species in which the seventh thoracic somite is fused with the first abdominal segment for a short distance on either side of the mid-dorsal line.

(*b*) A group to contain those species in which the seventh thoracic somite is not only fused with the first abdominal segment but also with the tergum of the sixth thoracic somite for a short distance on either side of the middle line.

(*c*) A group to contain the species *S. pallida*, Beddard, and *S. tuberculata*, Grube, in which the middle portion of the seventh thoracic somite is absent, and the first abdominal segment comes in contact with the tergum of the sixth thoracic somite. The coxal plates of the seventh are well developed and fused with the small lateral portions of the tergum of that somite.

In group (*a*) would be included *S. minuta*, Beddard, *S. bakeri*, Chilton, *S. pagenstecheri*, Pfeffer, *S. yongei*, Hale, *S. orbiculata*, n.sp., and *S. nototropis*, n.sp.; and in group (*b*) *S. australiensis*, Beddard, *S. elongata*, Beddard, *S. longicaudata*, Beddard, *S. bouvieri*, Richardson, *S. platygaster*, n.sp., and *S. aspera*, n.sp.

(5) That members of group (ii) are not restricted to Australian waters, for the group now includes, in addition to the Australian forms, *S. pagenstecheri*, Pfeffer, *S. bouvieri*, Richardson, and the new species *S. orbiculata*, *S. nototropis*, *S. platygaster* and *S. aspera*.

(6) That any new regrouping of the species would have to be based on the form of the more posterior thoracic somites, and would result in the formation of five genera, which would include the species represented in group (i), those in group (ii) subdivided as shown above into (*a*), (*b*) and (*c*), and those in group (iii) excluding *S. pagenstecheri* and *S. bouvieri*.

(7) That *S. beddardi* and *S. latifrons*, in which the lateral parts of the tergum and coxal plates of the last thoracic somite are present, and *S. pallida* and *S. tuberculata*, in which the central portion of the tergum of the seventh thoracic somite has disappeared, represent the opposite ends of a series in which the remaining species are graded.

After careful consideration, I have come to the conclusion that since the species represent such a compact genus, it is undesirable to subdivide it by the formation of four additional genera.

Since writing the above, Nordenstam's paper (1933) has been published; in this the author divides the genus *Serolis* into four sub-genera, namely, *Spinoserolis*, *Serolis*, *Homoserolis* and *Heteroserolis*.

The subgenus *Spinoserolis*, which corresponds to group (i) above, contains the two species *S. latifrons* and *S. beddardi.*

The subgenus *Serolis*, containing the majority of species, and corresponding to group (iii) above, is further sub-divided into five sections (called groups in Nordenstam's paper). If these sections are compared with the key (p. 278) of the present paper, it will be seen that they correspond very closely to the main subdivisions shown.

Section I contains the single species *S. gracilis* and corresponds with **B. I.** A. of the key.

Section II, containing the species *S. paradoxa*, *S. schythei* and *S. polaris*, agrees with the division **B. I.** B.

Section IV comprises the species *S. gaudichaudii*, *S. convexa* and *S. plana*, and corresponds to the section **B. I.** G. II. *a.* 2, to which group also belongs the species *S. laevis.*

Section V includes the single species *S. carinata.* The formation of this group depends on the statement that "the dorsal sutures of all the coxal plates are lacking on all the pereion segments". This statement, however, is inaccurate, for as in the majority of Serolids the terga of the first three free thoracic somites are separated from their respective coxal plates by sutures. Consequently *S. carinata* should be included in Section III.

Section III contains the remaining species of the subgenus *Serolis*: *S. trilobitoides*, *S. septemcarinata*, *S. antarctica*, *S. neaera*, *S. bromleyana*, *S. polita*, *S. meridionalis*, *S. glacialis*, *S. gerlachei* and *S. exigua.* In the key this section is represented by the subdivision **B. I.** C, excluding the subdivision **B. I.** C. II. *a.* 2; and includes, in addition to the species mentioned by Nordenstam, *S. cornuta* and the new species *S. kempi* and *S. elliptica*, as well as the transferred species *S. carinata.*

Nordenstam places the remaining species in his two subgenera *Homoserolis* and *Heteroserolis.* The former is characterized by the fact that "the tergum of the sixth (seventh actual) thoracic somite is coalesced with the first abdominal segment so that the suture-line between this segment and the abdomen has been effaced in the middle". In the latter the central portion of the tergum of the sixth (seventh actual) is entirely missing.

The definitions of these two sub-genera correspond with those of my groups ii *a* and ii *c* respectively, but Nordenstam has no subgenus corresponding to group ii *b* above, in which the terga of the sixth and seventh thoracic somites are fused with each other and with that of the first abdominal segment so that the suture-lines between these segments have been effaced in the middle.

The omission of this subdivision has resulted in a certain amount of confusion in Nordenstam's classification, as he has placed one member of this group, *S. bouvieri*, in his subgenus *Homoserolis*, and three others, *S. australiensis*, *S. longicaudata* and *S. elongata*, in the subgenus *Heteroserolis.* Thus, *Homoserolis* and *Heteroserolis* contain certain species which have characters in common, and which do not agree with the diagnostic characters of either subgenus. Since Nordenstam has based his classification on the degree of the reduction of, and coalescence between, the last three thoracic somites, it seems strange that he should have omitted this very definite type of modification, more especially since he had in his possession material representing three of the species concerned, namely *S. bouvieri*, *S. australiensis* and *S. longicaudata*.

It is obvious from the above, that Nordenstam's classification, as it stands, cannot be accepted. If the sub-division of the genus *Serolis* along the lines indicated above is to be established, then it is essential that a fifth subgenus should be formed to contain *S. bouvieri*, *S. elongata*, *S. australiensis*, *S. longicaudata* and the two new species *S. platygaster* and *S. aspera*. I maintain, however, that the genus is best left intact, and for this reason I do not suggest a name for this extra subdivision.

GENERAL MORPHOLOGY

The following notes, dealing with certain features in the anatomy of the Serolids, are included in the introductory part of this paper as they apply to the group as a whole and have not been described in detail in earlier papers. They include the structure of the maxillula, the maxilla and maxilliped, the interpretation of parts being based on the views expressed by Hansen (1925), as well as certain points of more general interest.

According to Hansen (1925) the **maxillula** in the Isopods consists only of a sympod made up of three segments: the endopod and exopod are wanting.

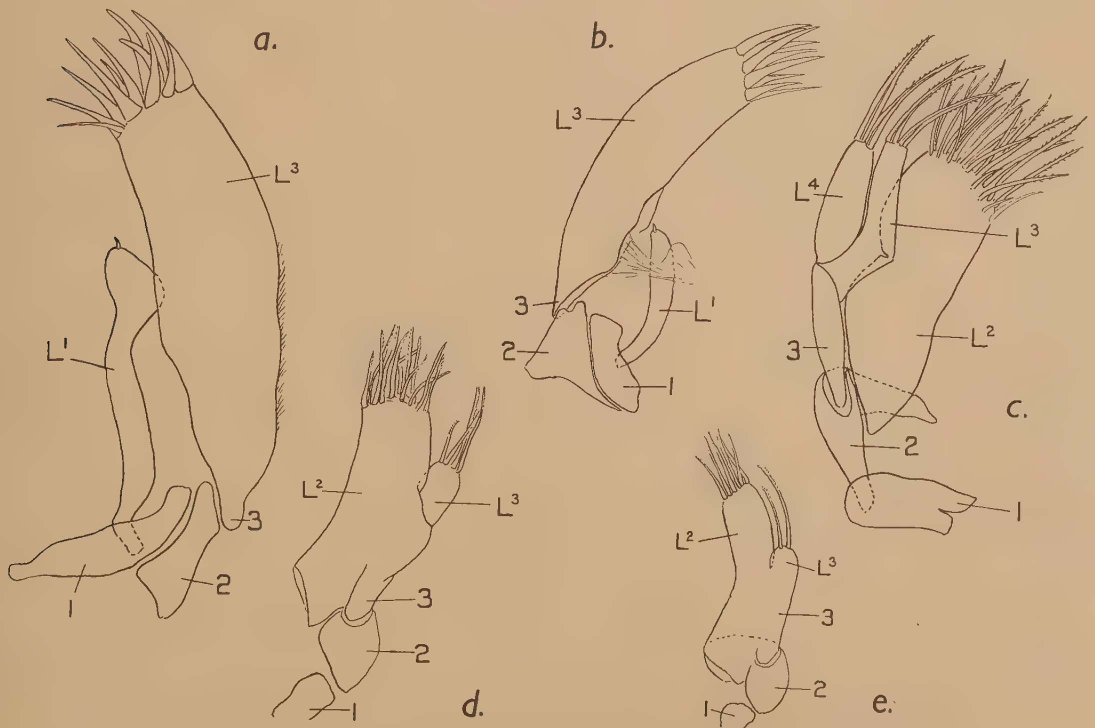

Fig. 1. The maxillula and maxilla of species of *Serolis*.

a, maxillula of *S. cornuta*, Studer: × 30. *b*, maxillula of *S. orbiculata*, n.sp.: × 140. *c*, maxilla of *S. cornuta*, Studer: × 30. *d*, maxilla of *S. nototropis*, n.sp.: × 104. *e*, maxilla of *S. orbiculata*, n.sp.: × 140.

In the majority of forms, as in the members of this family (Figs. 1 *a*, *b*), each maxillula consists of two endites directed distally and corresponding to the endites of segments 1 and 3 of the primitive axis; the inner endite L^1 is usually about two-thirds the length of the outer one, and is in the form of a curved rod, which may enlarge towards its distal end and bears one or two very short setae; it springs from the centre of a basal plate (1) which is the first segment of the primitive axis. At the outer side of the basal plate is a smaller though broader plate (2), corresponding to the second segment of the primitive axis, and from its outer distal extremity the second lobe of the maxillula arises, consisting of the fused third segment and its endite (L^3). This endite, which is stout and slightly curved inwards, broadens distally and has its obliquely truncate extremity armed with a double row of short stout spines.

In all the species of *Serolis* except *S. orbiculata*, n.sp., and *S. nototropis*, n.sp., the form of the maxilla agrees with that shown in Fig. 1 *c*. The three segments of the sympod are again represented: the first is in the form of a plate (1) from near the outer margin of which the second segment (2) arises; this segment is in the form of a stout rod, the upper third of which is expanded on its inner side to form a plate which appears to act as a place of attachment for the muscles which hold its corresponding endite (L^2) in position. The latter is a broad lobe which tapers towards its proximal end where it articulates with the upper half of the inner margin of its segment: its broad somewhat rounded distal extremity usually bears about twenty pectinate setae. Arising from a cup-like depression at the outer distal angle of the second segment of the sympod is the third segment (3) of the primitive axis; it lies in close proximity to the lower part of the second endite (L^2) and at its inner distal oblique extremity articulates with its corresponding endite. This lobe is cleft into two secondary lobes (L^3 and L^4), each of which terminates distally in a truncate extremity which usually bears two strong setae of the same type as those found on the second endite (L^2).

In the maxillae of *S. orbiculata* (Fig. 1 *e*) and *S. nototropis* (Fig. 1 *d*) the three segments of the primitive axis are again discernible, but the boundary of the second one is difficult to follow. In some specimens of *S. orbiculata* the boundary of the plate-like extension seemed to lie in the position indicated by the dotted line in the figure; the third segment (3), except for its proximal end, appears in *S. orbiculata* to be directly continuous with the endite (L^2) of the second segment as well as with its own endite (L^3); in *S. nototropis* the endite (L^3) of the third segment is separated by a suture.

In both species the endite (L^3) is small and undivided (cf. condition in other species), and that of *S. orbiculata* bears two and *S. nototropis* four long, pectinate setae on its truncate distal extremity. This type of maxilla may represent either a primitive or a secondary condition; in support of the former is the fact that according to Calman (1909, p. 198) Hansen regards the two endites L^3 and L^4 of segment 3 as having been derived from the division of a single endite. In this case the condition seen in *S. orbiculata*, where the endite (L^3) is directly continuous with its segment, would be more primitive than that in *S. nototropis*, where the endite (L^3) is cut off from its segment, and both would be more primitive than the type characteristic of the remaining species, where this endite is divided into two endites (L^3 and L^4). Since the condition in *S. nototropis* represents a stage prior to the division of the endite into two, the presence of four pectinate setae on its distal end may be significant, as in the majority of species this number is represented, there being two on each of the endites L^3 and L^4. A further point of some significance is that in both species the maxilliped is of the most primitive type. On the other hand, the fact that, as far as can be made out, the endite (L^2) of the second segment appears to be directly continuous with the third segment of the axis is more difficult to explain, and Dr Calman, who has very kindly examined the preparations of the maxillae of these two species, is inclined to believe that the condition seen is a secondary rather than a primitive one.

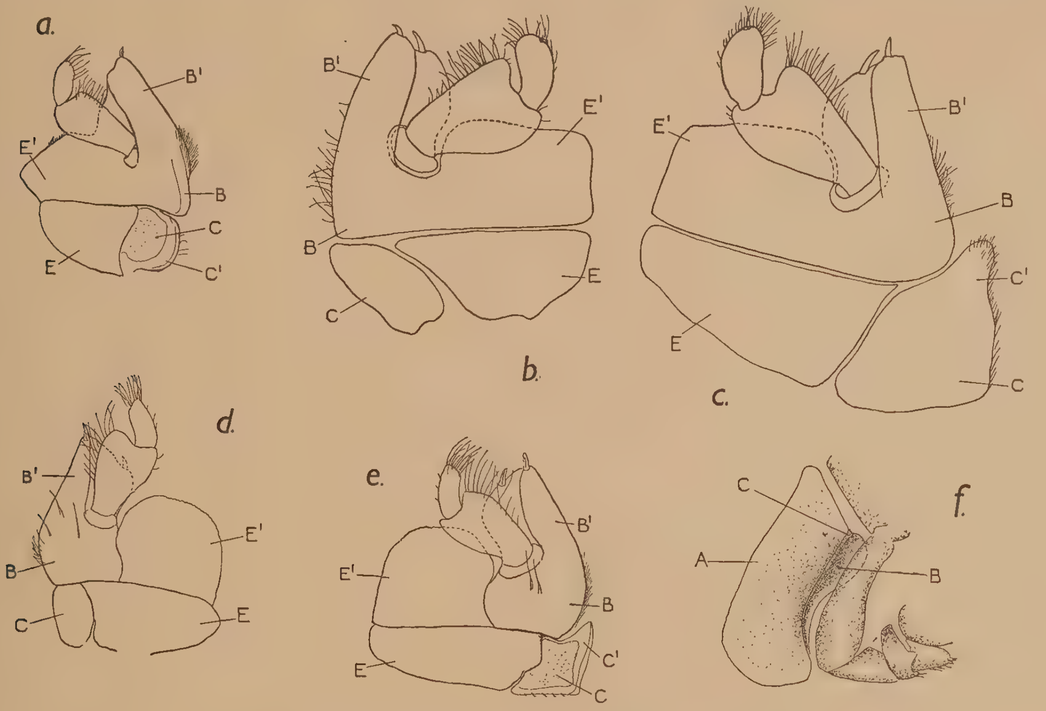

Fig. 2. The maxilliped, etc., of species of *Serolis*.

a, maxilliped of *S. exigua*, Nordenstam: × 87. *b*, maxilliped of *S. schythei*, Lütken, ♂: × 20. *c*, maxilliped of *S. schythei*, Lütken, ♀: × 25. *d*, maxilliped of *S. glacialis*, Tattersall, ♂: × 65. *e*, maxilliped of *S. glacialis*, Tattersall, ♀: × 65. *f*, ventral view of left second thoracic appendage and its associated brood lamella in a breeding ♀ of *S. discoverii*, n.sp.: × 35.

The sympod of the maxilliped consists of a short coxa (C) and a large basis (B) produced distally into a large endite (B'); the endopod or palp consists of three, sometimes four, more or less lamellar segments.

According to Hansen's description of the Isopod type of maxilliped, there is no exopod; but a plate-shaped epipod (E) is present, the proximal part (E) of which is marked off by a transverse suture from the distal major portion (E'); such a condition is figured by him for *Glyptonotus sibiricus*.

The parts of the maxilliped of certain species of *Serolis*, as for example that of *S. glacialis*, Tattersall (Fig. 2 *d*, *e*), might be interpreted in this way, but in some species, for example *S. schythei*, Lütken (Fig. 2 *b*, *c*), the larger distal portion of the epipod, instead of being freely articulated, is directly continuous with the proximal part of the basis, whilst in *S. nototropis*, n.sp. (Fig. 17 *b*), *S. orbiculata*, n.sp. (Fig. 15 *a*), *S. carinata*, Lockington, and *S. exigua*, Nordenstam (Fig. 2 *a*), this fusion is continued beyond the articulation of the base of the endopod, so that the latter appears to spring from the middle of a plate-like structure, which, according to Hansen's interpretation, would represent the basis with its endite fused with the distal portion of the epipod. In the two former species, *S. nototropis* and *S. orbiculata*, the fusion of the endite (*B′*) with the epipod (*E′*) is not as complete as in the two latter species.

The question then arises whether this condition is a secondary one resulting from the fusion of the basis (*B*) with its endite (*B′*) and the distal portion of the epipodite (*E′*), or whether it might not better be interpreted as primitive, in which case the "distal portion of the epipodite" (*E′*) must be regarded as a lamellar outgrowth of the basis. If this latter view is correct the condition met with in *S. carinata*, Lockington (Fig. 11 *a*), and *S. exigua*, Nordenstam (Fig. 2 *a*), is the most primitive; the next stage is represented by *S. orbiculata*, n.sp., and *S. nototropis*, n.sp. (Figs. 15 *a*, 17 *b*), where the separation of the endite (*B′*) from the lamella (*E′*) has begun; and this is followed by the stage seen in *S. schythei*, Lütken (Fig. 2 *b*), where the separation of the lamella (*E′*) reaches as far as the articulation of the endopod, but remains fused with the basis (*B*) behind this point. In the final stage, seen in *S. glacialis*, Tattersall (Figs. 2 *d*, *e*), the lamella (*E′*) is completely separated both from the basis (*B*) and its endite (*B′*).

In connection with this point I have examined the maxillipeds of a number of the more typical members of this order. In *Cirolana borealis*, Lilljeborg, the maxilliped consists of a sympod made up of a small coxa and a larger basis produced distally into a small endite; the palp consists of five segments, and a small epipod is also present, attached to the coxopodite. In the female of this species, during the breeding phase, a large lamellar outgrowth of the basis, exactly comparable in position with that of the so-called "distal portion of the epipod" is developed; lamella-like structures also occur on the coxa and on the epipod, along the inner and lower margin of the former and on the outer distal angle of the latter. Similar expansions also occur in the breeding females of *Eurydice elegantula*, Hansen, *Corallana antillensis*, Hansen and *Corallana tricornis*, Hansen, whilst in the female of *Ceratothoa banksii*, Leach, the lamella of the basis is fused with the basis, producing a condition directly comparable with that of the maxilliped of *S. schythei*, Lütken.

From these examples it seems reasonable to suppose that the "distal portion of the epipodite" of *Serolis* is morphologically the same as the "lamella of the basipodite" which is developed in the breeding females of the above-mentioned species, and that the four stages represented by *S. exigua*, *S. orbiculata*, *S. schythei* and *S. glacialis*, illustrate stages in the evolution of the appendage, in which the cumbersome structure represented by the basis, its endite and lamellar outgrowth, is gradually replaced by a more flexible structure in which first the distal portion of the lamella becomes free from the endite (B') and later from the basis (B) itself.

For these reasons, in this paper, I shall refer to the "distal portion of the epipodite" (Hansen) as the lamella of the basipodite, and the "proximal portion of the epipodite" as the epipodite proper.

Beddard (1884 *b*, p. 56, pl. iv, fig. 8) and Hodgson (1910, p. 28, pl. iv, fig. 5) describe and figure the maxillipeds of *S. bromleyana*, Suhm, and *S. trilobitoides*, Eights, respectively: in both the figures the coxopodite is shown fused with the epipodite. I have examined specimens of these species and find that a suture between the coxopodite and epipodite is clearly visible in each, so that the maxillipeds of all the species of *Serolis* fall into one or other of the four groups mentioned above.

The endopodite of the maxilliped of the majority of species of *Serolis* consists of three joints; in a few species, however, near the extremity of the third joint, at its outer angle, is a fourth small one, the distal extremity of which does not extend beyond that of the third: its truncate extremity bears several long setae. Such a joint is well developed in *S. platygaster*, n.sp. (Fig. 19 *a*). This small joint probably represents the fourth joint of the primitive five-jointed endopodite.

A further point of interest in connection with this limb is the modification in the form of the coxopodite of the female during the breeding phase. In the breeding female there is a very definite increase in the size of the coxopodite as compared with that of the male (Figs. 2 *b*–*e*), and this increase is brought about by a thin lamella-like extension of the posterior and inner margins of the joint (C), the distal angle of which is also often produced to form a small lobe. Delicate setae are developed along its inner margins.

This modification in the form of the coxopodite of *Serolis* has not been previously noted, and Calman (1909, p. 199), in dealing with the development of coxal lobes on these joints in ovigerous females of members of the order Isopoda, states that in *Serolis* no such lobes are developed. Nevertheless, the lamella-like extensions (C') of the coxopodites in the breeding females of Serolids must be regarded as coxal lobes. They are similar in form to the corresponding structures seen, for example, in the ovigerous females of *Phreatoicus australis*, Chilton, and these are homologous with, though less well developed than the corresponding lobes of the allied species *Ph. latipes* (Chilton) (see Sheppard, 1927, p. 87, fig. 1 (4) and p. 90, fig. 2 (1)).

Beddard (1884 *b*, pp. 15–17) gives an account of a number of secondary sexual characters in which the male differs from the female. To these may be added the following:

(1) In certain species, e.g. *S. glacialis*, Tattersall, *S. kempi*, n.sp., and *S. aspera*, n.sp., the number of joints in the flagellum of the antennule is considerably greater in the male than in the female.

(2) In *S. convexa*, Cunningham, *S. gaudichaudii*, Aud. et Edw., and *S. laevis*, Richardson, the form of the modified spines on the propodus of the second thoracic appendage shows a sexual variation (for details see the descriptions of the species).

(3) Long delicate setae are present on the outer margin of the propodus of the second

thoracic appendage of the adult male of *S. exigua*, Nordenstam. These are not found in the corresponding position in the female.

The so-called "**frontal sense organ**" first described by Grube (1875, p. 225) in his account of *S. paradoxa*, Fabricius, appears as an oval semi-transparent area on either side of the head on the lateral part of the cephalosome. Beddard (1884 *b*, p. 17) states that such a structure is present in many species of *Serolis*, and in a footnote further remarks that it generally has the form of a deep and narrow groove surrounded by a specially thickened rim, and that in *S. schythei*, Lütken, and *S. cornuta*, Studer, there is a pore on the under-surface of the epimeron exactly beneath it.

There is no doubt that such an area does appear in many species of *Serolis*, but I have failed to find the "thickened rim" surrounding a deep and narrow groove, or the "pore" on the under-surface. After the careful examination of a number of specimens of several species I have come to the conclusion that this area simply represents a certain thinness of the ventral chitinous coat brought about by the rubbing movement of the distal end of the propodus of the second thoracic appendage, which lies in this position when the appendage is not extended, and that it has no connection with any sensory function.

The **oostegites** appear in one of two forms: in the non-breeding female as chitinous, parallel-sided plates which reach the middle of the segment and are found on the second to the fifth thoracic somites; and in the breeding female as four pairs of large lamellae overlapping to form a complete marsupium. This overlapping alternates in successive segments: in the first and third somites the left lamella overlaps the right, and in the second and fourth the right overlaps the left. In no case do my observations agree with those of Studer (1879), who states that the lamellae of the right generally cover those of the left side.

It is interesting to note that in this family the form of the first pair of oostegites (Fig. 2 *f*) is similarly modified to that of *Asellus aquaticus* and of the members of the family Phreatoicidae. Each consists of a main posterior portion (*A*) which form the anterior boundary of the marsupium, and a smaller anterior portion (*B*) which envelops the base of the maxilliped of its own side. When viewed from below these two parts are seen to be separated from each other by a groove, at the bottom of which is a non-chitinous strip (*C*), this latter appearing to act as a hinge between the two parts of the lamella. It seems probable that, as in *Asellus aquaticus* and the Phreatoicidae (Sheppard, 1927, p. 91), the anterior parts of these lamellae, together with the coxal lobes of the maxillipeds, form an additional aerating apparatus for the marsupium.

In giving an account of the sexual characters of the Serolids, Beddard (1844 *b*, pp. 14, 15) states that when the brood lamellae of the female are fully developed "the sterna of the thoracic segments undergo a retrograde development and almost disappear", and that "the young appear to be actually contained within the body of the mother, the alimentary canal is pressed up against the dorsal surface of the body, and its cavity is reduced to a minimum".

With regard to the first part of this statement, it seems more correct to say that, following the moult at which the brood plates are replaced by the fully formed brood lamellae and the eggs are laid, the sterna of the thoracic somites remain soft, their usual function having been taken on by the chitinous middle portions of the brood lamellae. As a result of this, the cavity of the marsupium can be enlarged, not only by the bending downwards of the brood lamellae but also by the pushing upwards of the membranous ventral body wall. In this way accommodation for the increasing size of the developing embryos is ensured. The second part of Beddard's statement that "the young appear to be actually contained within the body of the mother" is inaccurate: the embryos undergo their development within the marsupium and are separated from the body cavity of the mother by the membranous ventral body wall.

An interesting result of the analysis of the adult female specimens of the species represented in the present collection is that breeding goes on all the year round, and that the number of females in the non-breeding condition is comparatively small.

The following table gives the details for *S. schythei* and *S. exigua* throughout the year. In the latter species, which is of a small size, the examination of the numerous specimens for the presence or absence of the brood plates was very tedious and was therefore omitted.

Month	*Serolis schythei*, ♀		*Serolis exigua*, ♀
	In breeding phase	In non-breeding phase	In breeding phase
Jan.	9	2	17+
Feb.	None collected	None collected	5
March	10	—	3
April	9	—	None collected
May	49	2	16+
June	33	—	28+
July	32	1	16+
Aug.	None collected	None collected	77+
Sept.	None collected	None collected	None collected
Oct.	18	10	5
Nov.	2	1	1
Dec.	13	20	16

From the above table it may be seen that in every month, when the collections included these species, females in the breeding phase were present, thus proving that they exhibit no definite breeding season. In this they agree with the Amphipod *Gammarus chevreuxi* (Sexton, 1924) and differ from the fresh-water Isopod *Asellus aquaticus* which appears to have a definite breeding season.

In *Asellus aquaticus*, and also in the members of the fresh-water family Phreatoicidae, females with the narrow plate-like type of brood lamellae as well as those with the broad type are found, and Unwin's observations (1920, p. 335) on *Asellus* show that the adult female, during the breeding season, passes through alternating phases of breeding and non-breeding, and that in the latter phase the broad lamellae are replaced by the narrow plate-like type. On the other hand, *Gammarus chevreuxi* shows no such alternation;

when maturity is reached the lamellae are fully formed, and a moult occurs after each brood is hatched. The brood-lamellae are fully formed at each moult and immediately a new brood is reared.

The fact that female Serolids with the narrow type of brood plate are comparatively rare, seems to suggest that those present are immature specimens rather than mature females in the non-breeding phase, and that, as in *Gammarus*, once maturity is reached, the brood-lamellae are fully formed after each moult and a new brood is reared. It would be interesting to know how far these two breeding methods are characteristic of fresh water and salt water respectively.

Nordenstam (1933) has dealt with "the scales and setae in the family Serolidae" (pp. 14–38) in great detail: many of the types described by him are considered in the present paper under the various descriptions of species.

KEY TO ALL KNOWN SPECIES OF *SEROLIS*.

A. Small dorso-lateral portions of the tergum and of the coxal plates of the eighth thoracic somite present. Endopod of the uropod absent. All free thoracic somites (3rd–8th) separated from their coxal plates by sutures. Hindmost suture of seventh thoracic somite complete.

- **I.** Dorsal surface of head and body strongly sculptured; terminal segment studded with tubercles ... ... 1. *S. beddardi*, Calman.
- **II.** Dorsal surface of head and body segments nearly smooth; terminal segment smooth except for a median and a pair of sub-marginal ridges ... ... 2. *S. latifrons*, White.

B. Tergum and coxal plates of the eighth thoracic somite absent. Both endopod and exopod of the uropod usually present.

- **I.** Tergum of seventh thoracic somite articulating freely with that of the first abdominal segment, that is, the hindmost suture of the seventh somite is complete.
  - A. All free thoracic somites (3rd–7th) separated from their coxal plates by sutures; eyes small and inconspicuous ... ... 3. *S. gracilis*, Beddard.
  - B. Only the first four free thoracic somites (3rd–6th) separated from their coxal plates by sutures.
    - I. Coxal plates of seventh thoracic somite extend backwards to about the middle of the terminal segment, pleural plates of second and third abdominal segments short, not extending far beyond the anterior margin of the terminal segment 4. *S. paradoxa*, Fabricius.
    - II. Coxal plates of seventh thoracic somite extend backwards, in the male, for some distance beyond the posterior extremity of the terminal segment; pleural plates of second abdominal segment long, extending beyond the posterior extremity of the terminal segment, those of the third segment short ... ... 5. *S. schythei*, Lütken.[1]
    - III. Coxal plates of seventh thoracic somite extend to the postero-lateral angles of the terminal segment, but *not as far as* the pleural plates of the second abdominal segment; those of the third segment extend backwards to about the middle of the terminal segment ... ... 6. *S. polaris*, Richardson.

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[1] *S. serrei*, Lucas, has not been recorded since first briefly described in 1877 and is possibly identical with *S. schythei*.

C. Only the first three free thoracic somites (3rd–5th), separated from their respective coxal plates by sutures.

- I. Coxal plates of seventh thoracic somite not extending backwards beyond the pleural plates of the second and third abdominal segments.
  - *a*. Pleural plates of second abdominal segment extending beyond those of third. Terminal segment with well-developed spine in anterior median dorsal line, followed by a median carina extending to its extremity; on either side of median, two lateral oblique carinae terminating in small spines some distance from the lateral margins ... ... 7. *S. glacialis*, Tattersall.
  - *b*. Pleural plates of third abdominal segment extending beyond those of second.
    - 1. Extremity of terminal segment trifid; dorsal surface of terminal segment with a median carina and three lateral ones on either side of it. 8. *S. septemcarinata*, Miers.
    - 2. Extremity of terminal segment *not* trifid; terminal segment broader than long or about as broad as long.
      - α. Terminal segment with a well-developed spine in the antero-dorsal line, followed by a median carina.
        - (i) Median carina slight, terminating in a spine *at some* distance from the upturned, pointed posterior extremity; two lateral oblique carinae on either side, terminating in spines; two inner terminating in a line with the end of the median carina ... ... 9. *S. kempi*, n.sp.
        - (ii) Median carina extending to extremity of segment, with two lateral oblique carinae on either side of it, each terminating in a small spine some distance from the lateral margins ... ... 10. *S. polita*, Pfeffer.
      - β. Terminal segment *without* well-marked dorsal spine in an antero-median position.
        - (i) Uropoda broad and extending beyond the posterior extremity of the terminal segment; body oval in shape and without spines 11. *S. elliptica*, n.sp.
        - (ii) Uropoda *not* broad and extending beyond the posterior extremity of the terminal segment; cephalosome with dorsal posterior margin produced backwards to form a median spine reaching to near the middle of the first free (3rd) thoracic somite; spine less pronounced in the female 12. *S. exigua*, Nordenstam.
- II. Coxal plates of seventh thoracic somite extending beyond the pleural plates of the second and third abdominal segments.
  - *a*. Pleural plates very short, not extending beyond the anterior margin of the terminal segment.
    - 1. Terminal segment with three dorsal carinae, the median one of which is *not* interrupted in the middle: lateral carinae following the outline of the segment at some distance within it and meeting the central one at its posterior extremity ... ... 13. *S. carinata*, Lockington.
    - 2. Terminal segment with three dorsal carinae, the median one of which is interrupted in the middle.
      - α. Lateral carinae well developed and ending in spines; terminal segment narrowing posteriorly; body pear-shaped ... 14. *S. convexa*, Cunningham[1].
      - β. Lateral carinae are well marked; terminal segment almost circular in outline; body broadly oval ... ... 15. *S. gaudichaudii*, Aud. et Edw.
      - γ. Median and lateral carinae almost obsolete ... 16. *S. laevis*, Richardson.

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[1] *S. plana*, Dana, is probably identical with *S. convexa*.

b. Pleural plates of second and third abdominal segments extending *beyond* the anterior margin of the terminal segment.

1. Coxal plates of seventh thoracic somite extending backwards for about two-thirds of the length of the terminal segment (excluding the terminal spine if present).

α. Median dorsal portion of the cephalosome produced backwards into a spine which extends to the middle of the fourth thoracic somite 17. *S. gerlachei*, Monod.

β. Median dorsal spine of cephalosome absent; posterior extremity of terminal segment produced to form a long spiniform process, the lateral margins of which are serrated; eyes devoid of pigment ... 18. *S. meridionalis*, Hodgson.

2. Coxal plates of seventh thoracic somite extending as far, or nearly as far, as the posterior extremity of the terminal segment.

α. Coxal plates of seventh thoracic somite, in the male, extending backwards almost as far as the posterior extremity of the terminal segment; pleural plates of second and third abdominal segments to a short distance beyond the articulation of the uropod; terminal segment longer than broad; body almost circular in outline ... ... 19. *S. cornuta*, Studer.

β. Coxal plates of seventh thoracic somite extending backwards to a point not far beyond the articulation of the uropod and only just beyond the posterior extremities of the pleural plates; terminal segment broader than long; body broadly ovate in shape ... ... 20. *S. trilobitoides*, Eights.

3. Coxal plates of seventh thoracic somite long and extending backwards beyond the posterior extremity of the terminal segment.

α. Eyes absent; coxal plates comparatively short and flat, those of the seventh thoracic produced backwards to a *short* distance beyond the posterior extremity of the terminal segment; pleural plates of third abdominal segment slightly longer than those of the second, and reaching to the basal joints of the uropoda ... ... 21. *S. antarctica*, Beddard.

β. Eyes present but not deeply pigmented; coxal plates long and spiniform, those of the seventh thoracic somite extending for a considerable distance beyond the extremity of the terminal segment; pleural plates of third abdominal segment in the male produced backwards as far as extremity of the terminal segment; those of second to a short distance beyond: eyes whitish yellow in colour ... ... 22. *S. bromleyana*, Suhm.

c. Pleural plates of second abdominal segment extending for some distance beyond the posterior extremity of the terminal segment; those of the third segment *short*, not reaching beyond the antero-lateral margin of the terminal segment; eyes large, with bluish black pigment ... ... 23. *S. neaera*, Beddard.

II. Hindmost suture of seventh thoracic somite obsolete in the mid-dorsal line, so that for a short distance the tergum is fused with the first abdominal segment; the third to the fifth thoracic somites separated from their coxal plates by sutures.

A. Hindmost suture of sixth thoracic somite complete.

I. Coxal plates of seventh thoracic somite *not* extending backwards as far as the posterior extremities of the pleural plates of the second and third abdominal segments.

a. Terminal segment almost triangular in shape, with a dorsal median keel, ending posteriorly in a blunt prolongation; thoracic somites each with median tubercle, and free somites each with a lateral tubercle on either side, close to the junction of the tergum with its coxal plate ... ... 24. *S. minuta*, Beddard.

b. Terminal segment with a conspicuous median dorsal keel; posterior extremity narrow and rounded; dorsal surface of body without median or lateral tubercles 25. *S. bakeri*, Chilton.

c. Terminal segment with slight median dorsal keel; tubercles on cephalosome and on thoracic somites absent ... ... 26. *S. yongei*, Hale.

II. Coxal plates of seventh thoracic somite extending backwards beyond the posterior extremities of the pleural plates of the second and third abdominal segments.

a. Pleural plates short, not extending beyond the broad anterior margin of the terminal segment; terminal segment triangular in shape with rounded angles, slight median dorsal carina present ... ... 27. *S. orbiculata*, n.sp.

b. Pleural plates of second and third abdominal segments extending beyond the anterior margin of the terminal segment; those of the third slightly the longer.

1. Terminal segment with median dorsal and two lateral carinae on either side, the outer one of which follows the outline of the terminal segment 28. *S. nototropis*, n.sp.

2. Terminal segment roughly five-sided, with a well-developed spine in an antero-median position on the dorsal surface, followed by a low median carina, on either side of which are two lateral carinae each terminating in a small spine some distance from the lateral margin ... ... 29. *S. pagenstecheri*, Pfeffer.

B. Hindmost suture of sixth thoracic somite obsolete in the mid-dorsal line, so that for a short distance the terga of the sixth and seventh somites are fused with each other and with that of the first abdominal segment.

I. Position of missing suture between the sixth and seventh somites indicated by a groove; uropod very small, endopod wanting ... ... 30. *S. platygaster*, n.sp.

II. Groove absent.

a. Coxal plates of seventh thoracic somite of male produced backwards for a short distance beyond the attachment of the uropod, and beyond the level of the pleural plates of the third abdominal segment; those of female extending backwards as far as the pleural plates of the third abdominal segment, which, in both sexes, are longer than those of the second.

1. Margins of coxal and pleural plates and of terminal segment very much thickened ... ... 31. *S. bouvieri*, Richardson.

2. Margins not thickened; terminal segment with a well-developed spine in antero-median position, followed by a median carina, on either side of which are two lateral carinae terminating at some distance from margins in small spines ... ... 32. *S. aspera*, n.sp.

b. Coxal plates of seventh thoracic somite *not* reaching backwards as far as the attachment of the uropod. Pleural plates short.

1. Coxal plates of seventh thoracic somite of male extending backwards to just beyond the pleural plates of the third abdominal segment; surface of body covered with tubercles ... ... 33. *S. australiensis*, Beddard.

2. Coxal plates of seventh thoracic somite extending backward to the level of the extremities of the pleural plates of the second abdominal segment but not as far as those of the third.

α. Each of the segments of the body with a dorsal median curved, hook-like spine, and with a row of short tubercles near its hinder border 34. *S. elongata*, Beddard.

β. Segments with median spines and lateral tubercles. Terminal segment long, with incurved sides, and with posterior truncate extremity concave 35. *S. longicaudata*, Beddard.

III. Tergum of seventh thoracic somite absent except for small lateral portions which are continuous with the coxal plates, these are of normal size; hindmost suture of sixth thoracic somite complete; third to fifth thoracic somites separated from their coxal plates by sutures.

A. Head triangular in shape, with apex directed backwards and produced into a large median spine ... ... 36. *S. pallida*, Beddard.

B. Head four-sided; pointed tubercles along the posterior margins of the anterior thoracic somites, and median dorsal tubercles on all the segments ... ... 37. *S. tuberculata*, Grube.

DESCRIPTION OF SPECIES

1. **Serolis beddardi**, Calman (Fig. 3).

S. beddardi, Calman, 1920, p. 299, figs. 1–3.

Occurrence. St. 174: South Shetlands, 5–10 m.; 4 ♂♂, 1 ♀ (b.) and 9 immature specimens.

DIAGNOSTIC CHARACTERS. The largest male in the collection measures 22 mm. in length and 17 mm. in greatest breadth, a size approximately the same as that of Calman's specimen; the adult female is incomplete, but has a breadth of 15·5 mm., which is 1 mm. less than that of Calman's largest specimen.

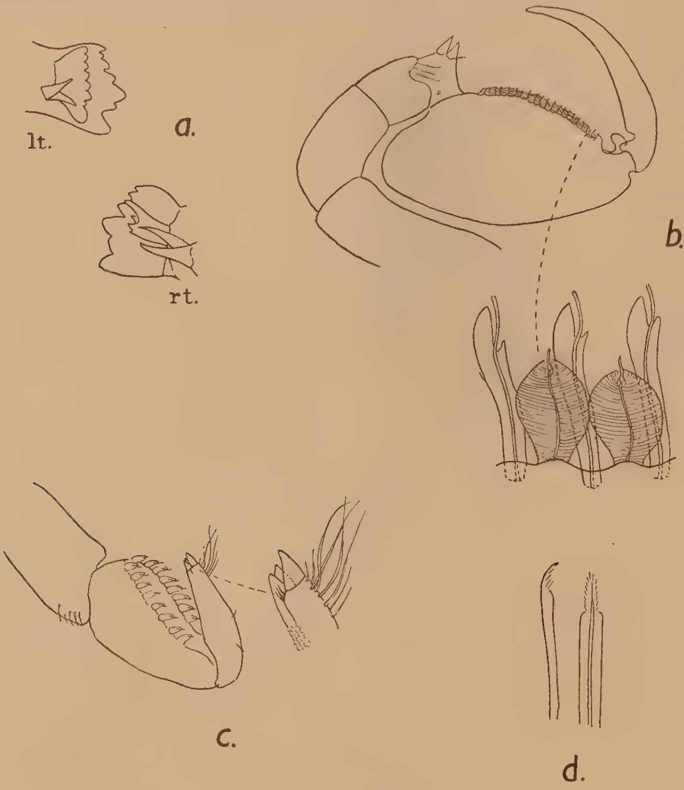

Fig. 3. *Serolis beddardi*, Calman.

a, cutting edges of mandible: × 20. *b*, second thoracic appendage: × 7. *c*, third thoracic appendage of ♂: × 16. *d*, type of setae found on limbs.

The dorsal surface of the head and body segments is strongly sculptured and the terminal segment is studded with rounded tubercles which lie between the median and sub-marginal ridges; a pair of short sub-median ridges is also present; the eyes are rather small, reniform in shape and containing black pigment.

The coxal plates, which are all fringed with long setae, are comparatively small and are all separated from their respective thoracic somites by sutures; in this species, as Calman points out, a vestige of the tergum and of the coxal plate of the last thoracic somite may be seen on either side of the first abdominal segment. The coxal plates of the seventh thoracic somite (sixth free) do not extend posteriorly beyond the base of the terminal segment, which is broad, and extends laterally beyond the pleural plates of the second and third abdominal segments.

Remarks. The original account of this species does not include descriptions of the appendages: a few notes on them are given here.

The surfaces of both the antennules and the antennae are covered with minute rounded scales. The first peduncular joint of the antennule is short, the second and third are each about twice the length of the first; the fourth is very small, being about half the length of the first flagellar joint; the posterior margins of the second, third and fourth joints are densely fringed with long setae; the flagellum consists of nineteen joints. The first three joints of the antenna are very short, the fourth is twice as long as the third, and the fifth twice as long as the fourth; the posterior distal angle of the fifth joint is produced into a rounded process and its posterior border is fringed with long setae; similar setae are present in tufts on the anterior margin, and a group is also present on the posterior distal angle of the fourth joint; the flagellum consists of nineteen joints, the distal one of which is very small and bears a number of delicate setae.

The mandibles are of the usual form; the terminal joint of the palp bears the usual type of setae, but these are absent from the second joint, their place being taken by a few long simple setae which are scattered along its margin, as well as along that of the basal joint. The form of the cutting edge of both the right and the left mandible may be seen from Fig. 3 *a*. The outer lobe of the maxillula bears eleven strong spines on its truncate distal extremity; the inner lobe is about two-thirds the length of the outer and bears a single short seta on its much broadened distal end. There are two pectinate setae on the outer and four on the inner lobe of the maxilla, and about twenty on the fixed lobe.

The maxilliped has its surface covered with minute imbricating scales; the basipodite is separated by a suture from the lamella, which is longer than broad with a concave distal extremity; the lower half of its outer margin is fringed with long hairs, whilst the upper half is toothed: the inner margin of the basipodite is fringed with delicate setae, scattered amongst which are stronger ones. The second joint of the palp is broad, whilst the terminal joint is long and almost parallel-sided; setae are present on its rounded distal extremity and on the upper inner margin of the second joint.

The second thoracic appendage (Fig. 3 *b*) is short and robust; the propodus is broad and its inner margin is armed with a row of broadly rounded processes alternating with a row of modified spines; the distal edge of the carpus is crenulate and bears two short stout spines. The third thoracic appendage of the male (Fig. 3 *c*) is considerably longer than the second; the propodus has its inner margin armed with a double row of spines of the type usually found on this limb—there are eight spines in each row; the dactylus ends distally in a strong spine, arising just behind which are two other spines and three short setae; its inner margin appears to be raised into a number of minute papillae. With the exception of the merus and dactylus, the other joints of the 4–7 appendages are fringed with strong setae, many of which are of the type shown in Fig. 3 *d*, whilst some, at the distal ends of the joints, bear much stronger pectinations.

The first three pairs of pleopods are of the usual type; the protopodite of each is somewhat triangular, with the prolonged angle bearing three plumose setae on the first and two on each of the second and third pleopods: long delicate hairs are present around the margins of the protopodite and also fringe the anterior margins of both the exopodite and endopodite. The suture of the exopod of the fourth pleopod is oblique and towards the distal end; both margins of the exopod are fringed with hairs, those of the inner margin are replaced towards the distal end by plumose setae, and a group of these setae surround the distal extremity; the ventral surface of the exopod is covered with long scattered setae which increase in size and number distally; the endopod has a rounded distal extremity and bears no setae.

The uropoda have already been described by Calman (1920, pp. 300, 304, fig. 3). Each consists of a protopodite which is prolonged into an acute point; the exopod is small and spiniform; the endopod is wanting.

DISTRIBUTION. The species has not been recorded since Calman described it; the present specimens come from the type locality, Deception Island, South Shetlands.

2. **Serolis latifrons, White.**

S. latifrons, White, 1847, p. 106; Miers, 1875, p. 74; 1876, p. 116; Smith, 1876, p. 63; 1879, p. 204; Studer, 1879, p. 26; Beddard, 1884*b*, p. 44, pl. ii, figs. 1–4; Vanhöffen, 1914, p. 518; Calman, 1920, p. 299.

DIAGNOSTIC CHARACTERS. The largest specimen in the Challenger collection is a female 32 mm. in length and 24 mm. in greatest breadth; the males are proportionately broader than the females, the largest measuring 28 mm. in length and 24 mm. in breadth: the body is oval in shape with an almost smooth dorsal surface.

In this species, as in *S. beddardi*, Calman, minute lateral portions of the tergum of the eighth thoracic somite are present, and separated from them by sutures are small coxal plates. The coxal plates of the remaining free thoracic somites are separated from their respective somites by sutures; they are closely applied together and those of the seventh somite do not extend backwards as far as the bases of the uropoda.

The terminal segment is almost triangular in shape, its anterior margin extends laterally beyond the pleural plates of the second and third abdominal segments, which are short; near the antero-lateral margin, on either side, is a notch into which the base of the protopodite of the uropod fits. A median and a pair of lateral sub-marginal ridges are present on the dorsal surface.

The protopodite of the uropod is produced distally as an acute prolongation; the exopod is reduced and spiniform and the endopod is absent.

DISTRIBUTION. Off Kerguelen.

3. **Serolis gracilis**, Beddard.

S. gracilis, Beddard, 1884*a*, p. 332; 1884*b*, p. 61, pl. iii, figs. 7–13.

Diagnostic characters. The largest male specimen in the Challenger collection measures 21 mm. in length and 22 mm. in greatest breadth; the females are much smaller, being 9 mm. in length and 8 mm. in greatest breadth.

The outline of the body is almost circular and its surface is covered with scattered pits; its colour in alcohol is a dark slate-blue, varying to reddish yellow upon the terga of the posterior thoracic somite and the abdominal segments: the cephalosome is strongly convex between the eyes, whilst the antero-lateral areas are flat and depressed; the rostrum is very short; the eyes are small and appear to contain little or no pigment.

The coxal plates are flat and sickle-shaped and gradually increase in length from before backwards: in the male those of the seventh somite extend for some distance beyond the end of the terminal segment, whilst those of the female are much shorter and do not reach to its extremity. All the free thoracic somites (3–7) are separated from their respective coxal plates by sutures.

The pleural plates of the second abdominal segment are longer than those of the third; in the male they extend for a short distance beyond the end of the terminal segment, whilst those of the female do not extend farther than the middle of the segment; the plates of the third segment in the male are about the same length as those of the second in the female, whilst the third in the female are considerably shorter.

The terminal segment is squarish in outline, it possesses "a slight longitudinal median keel which is crossed at right angles by a sinuous ridge with three convexities, one median and two lateral, which correspond to the spines on the caudal shield of *S. neaera*, Beddard and *S. schythei*, Lütken; about the end of the anterior third of the caudal shield is a short flat spine in the middle line and two oblique ridges, one on either side of this spine; the lateral portions of the caudal shield are bent down".

In the male, plumose hairs are present on the inner margin of the merus and carpus of the third appendage and on the merus, carpus and propodus of the last.

Remarks. My observations agree with those of Beddard except that in his description of the maxilliped he says that "the stipes and lamina are not separated by a complete suture" and in his figure (pl. iii, fig. 10) this suture is also omitted. In the specimens at the British Museum a suture between the basipodite and the lamella of this appendage is clearly visible.

Distribution. Off Pernambuco, South America, in 675 fathoms.

4. **Serolis paradoxa**, Fabricius.

Oniscus paradoxus, Fabricius, 1775, p. 296; 1787, p. 240.
Cymothoa paradoxa, Fabricius, 1792–8, Suppl. pp. 304, 503.
Serolis fabricii, Leach, 1818, p. 340.
Serolis orbignyi, Audouin and Milne-Edwards, 1841, p. 25.
Serolis orbigniana, Milne-Edwards, 1840, p. 232; Grube, 1875, p. 225.
Serolis paradoxa, Miers, 1881, p. 61; Beddard, 1884*b*, p. 33, pl. v, figs. 12–14; Nordenstam, 1933, pp. 51–5, text-figs.

DIAGNOSTIC CHARACTERS. The male of this species is a little broader in proportion to its length than is the female, the largest male in the Challenger collection measuring 24·5 mm. in length and 25 mm. in breadth, and the largest female 27·5 mm. in length and 26 mm. in breath.

The head is broadest anteriorly and in this point differs from that of *S. schythei*, Lütken, and *S. polaris*, Richardson, two closely allied species, in both of which it is broadest at about the level of the eyes. The flagellar joints (7–16, in one specimen) of the antenna of both sexes are furnished with a series of short recurved hooks which correspond with the "lamellar-like" structures of *S. schythei*.

The body is less flattened than in the two allied species; the coxal plates are smaller, and those of the first four free somites are separated from them by sutures. I noticed that in this species the positions of the sutures on the tergum of the fifth free somite, which have disappeared, are indicated by shallow grooves. The coxal plates of the seventh somite are produced backwards to a level about the middle of the terminal segment; the pleural plates of both the second and third abdominal segments are short, and do not extend far beyond the anterior margin of the terminal segment; those of the third are slightly longer than those of the second segment.

The ischium, merus and carpus of the third appendage in the male are furnished with abundant plumose hairs arranged in two rows: these are absent from the corresponding joints of this appendage in the two allied species. The terminal segment is more triangular than in the other two species, and it bears on its dorsal surface a median longitudinal keel on either side of which is a lateral one. A strong median spine is situated in an anterior position, and running parallel to the anterior margin is a transverse carina of which only traces exist in *S. schythei*; the transverse ridge of the latter is absent in *S. paradoxa*.

DISTRIBUTION. Off the Falkland Islands, and adjacent shores of Patagonia.

5. Serolis schythei, Lütken (Figs. 2 *b*, *c*, 4 *a*, *b*; Plate XIV, fig. 1).

S. schythei, Lütken, 1858, p. 98, pl. i, figs. 12, 13; Grube, 1875, p. 220, pl. vi, fig. 1; Beddard, 1884*b*, p. 40, pl. ii, figs. 5–13; Tattersall, 1921, p. 227; Giambiagi, 1925, pp. 11–12, pl. ii, fig. 3; Nordenstam, 1933, pp. 55–7, text-figs.

Occurrence. St. 51: East Falkland Island, 115 m.; 19 ♂♂, 45 ♀♀ (b.), and a number of immature specimens. St. 223: Cape Horn, 63 m.; 6 ♀♀ (b.), 4 immature. St. WS 72: 51° 07′ S, 57° 34′ W, 79 m.; 2 ♂♂. St. WS 73: 51° 01′ S, 58° 53′ W, 121–130 m.; 5 ♂♂, 4 ♀♀ (b.), 2 immature. St. WS 75: 51° 01′ 30″ S, 60° 31′ W, 72 m.; 2 ♂♂, 1 ♀ (b.), 1 immature. St WS 76: 51° 00′ S, 62° 02′ 30″ W, 207–205 m.; a number of immature. St. WS 78: 51° 01′ S, 68° 04′ 30″ W, 91–95 m.; 3 immature. St. WS 79: 51° 01′ 30″ S, 64° 59′ 30″ W, 132 m.; 1 ♀ (b.), a number of immature. St. WS 80: 50° 57′ S, 63° 37′ 30″ W, 152–157 m.; 2 ♂♂, 4 ♀♀ (b.), a number of immature. St. WS 83: 14 miles S 64° W of George Island, East Falkland Island, 137–129 m.; 1 immature. St. WS 90: 13 miles N 83° E of Cape Virgins Light, Argentine Republic, 82–81 m.; 3 ♂♂, 3 ♀♀ (b.), and a number of immature. St. WS 210: 50° 17′ S, 60° 06′ W, 161 m.; 1 ♂, 1 ♀ (b.), 1 immature. St. WS 211: 50° 17′ S, 60° 06′ W, 174 m.; 1 immature. St. WS 214: 48° 25′ S, 60° 40′ W, 208–219 m.; 1 ♀ (non-b.), 1 ♀ (b.), a number of immature. St. WS 215: 47° 37′ S, 60° 50′ W, 219–146 m.; 5 immature. St. WS 216: 47° 37′ S, 60° 50′ W, 219–133 m.; 2 ♂♂, 5 ♀♀ (b.), a number of immature. St. WS 219: 47° 06′ S, 62° 12′ W, 116–114 m.; 14 ♂♂, 22 ♀♀ (b.), a number of immature. St. WS 225: 50° 20′ S, 62° 30′ W, 162–161 m.; 2 immature. St. WS 226: 49° 20′ S, 62° 30′ W, 144–152 m.; 1 immature.

St. WS 229: 50° 35′ S, 57° 20′ W, 210–271 m.; 1 ♀ (b.), 5 immature. St. WS 233: 49° 25′ S, 59° 45′ W, 185–175 m.; 3 ♀♀ (b.), 2 ♂♂, a number of immature. St. WS 234: 48° 52′ S, 60° 25′ W, 195–207 m.; 2 ♀♀ (b.), 6 immature. St. WS 235: 47° 56′ S, 61° 10′ W, 155 m.; 1 ♂, 3 ♀♀ (b.), 1 immature. St. WS 236: 46° 55′ S, 60° 40′ W, 273–300 m.; 1 immature. St. WS 237: 46° 00′ S, 60° 05′ W, 150–256 m.; 10 ♀♀ (b.) 1 ♀ (non-b.), 12 ♂♂, a number of immature. St. WS 239: 51° 10′ S, 62° 10′ W, 196–192 m.; 2 ♀♀ (b.), 1 ♂, 1 immature. St. WS 243: 51° 06′ S, 64° 30′ W, 144–141 m.; 11 immature. St. WS 244: 52° 00′ S, 62° 40′ W, 253–248 m.; 2 ♂♂, 3 immature. St. WS 245: 52° 36′ S, 63° 40′ W, 304–290 m.; 3 immature. St. WS 752: 51° 20′ S, 63° 17′ W, 160 m.; 1 young ♂. St. WS 754: 51° 09′ 30″ S, 58° 54′ W, 106 m.; 1 immature. St. WS 758: 48° 32′ S, 61° 19′ W, 112 m.; a number of immature. St. WS 763: 44° 14′ S, 63° 28′ W, 87–82 m.; 1 immature. St. WS 765: 45° 07′ S, 60° 28′ 15″ W, 113–118 m.; 3 ♀♀ (b.), 55 immature. St. WS 771: 42° 41′ 45″ S, 60° 31′ W, 90 m.; 7 ♂♂, 8 ♀♀ (b.), 10 ♀♀ (non-b.), a number of immature. St. WS 772: 47° 28′ S, 60° 51′ W, 309–162 m.; 13 ♂, 7 ♀ (b.), a number of immature. St. WS 774: 47° 08′ S, 62° 02′ W, 139–144 m.; 1 ♀ (non-b.). St. WS 775: 46° 44′ 45″ S, 63° 33′ W, 115–110 m.; 6 ♂♂, 2 ♀♀ (b.), a few immature. St. WS 776: 46° 18′ 15″ S, 65° 02′ 15″ W, 107–99 m.; 1 ♂. St. WS 781: 50° 30′ S, 58° 50′ W, 148 m.; 2 ♂♂, a number of immature. St. WS 782: 50° 29′ 15″ S, 58° 23′ 45″ W, 141 m.; 11 ♂♂, 7 ♀♀ (b.), 8 ♀♀ (non-b.), a number of immature. St. WS 783: 50° 02′ 45″ S, 60° 14′ W, 159–0 m.; 5 ♂♂, 1 ♀ (b.), 2 ♀♀ (non-b.), 7 immature. St. WS 786: 49° 07′ S, 63° 55′ W, 133–119 m.; 7 immature. St. WS 787: 48° 44′ S, 65° 24′ 30″ W, 106–110 m.; 5 ♂♂, 2 ♀♀ (non-b.), a number of immature. St. WS 791: 45° 41′ 45″ S, 62° 45′ W, 96–101 m.; 1 ♀ (b.), 1 ♀ (non-b.), a number of immature. St. WS 797: 47° 45′ 36″ S, 64° 20′ W, 115–111 m.; 2 ♀♀ (non-b.), a number of immature. St. WS 802: Haul A, 50° 45′ 45″ S, 61° 22′ W, 128–132 m.; 1 ♂, 2 ♀♀ (b.), 1 ♀ (non-b.), several immature. St. WS 802: Haul B, 50° 43′ 45″ S, 61° 26′ W, 132–139 m.; 9 ♂♂, 6 ♀♀ (b.), 6 ♀♀ (non-b.), several immature. St. WS 814: 51° 45′ 15″ S, 66° 40′ W, 111–118 m.; 1 immature. St. WS 815: 51° 51′ 45″ S, 65° 44′ W, 132–162 m.; 1 immature. St. WS 816: 52° 09′ 45″ S, 64° 56′ W, 150 m.; 1 ♂, 7 immature. St. WS 818: 52° 31′ 15″ S, 63° 25′ W, 272–278 m.; 7 immature. St. WS 824: 52° 29′ 15″ S, 58° 27′ 15″ W, 146–137 m.; 2 immature. St WS 825: 50° 50′ S, 57° 15′ 15″ W, 135–144 m.; 1 ♂, 6 ♀♀ (b.), several immature. St. WS 866: 50° 37′ 45″ S, 64° 15′ W, 137–144 m.; 1 immature specimen.

Diagnostic characters. The largest male in the collection measures 28 mm. in length and 33 mm. in greatest breadth, whilst a female in the breeding phase measures 23 mm. in length and 23 mm. in greatest breadth. The male (Plate XIV, fig. 1) is thus considerably broader in proportion to its length than the female, the latter being almost circular in outline.

The head is broadest at the eyes, which are large and prominent. Between them are three somewhat triangular areas, the two lateral of which are raised to form low prominences, while the central one forms the posterior boundary of the head. The body is flattened; the coxal plates are sickle-shaped, with their outer halves projecting freely, those of the first four free somites are marked off by sutures. In the male the coxal plates of the seventh thoracic somite are long, extending, in the largest specimen, for the space of about 5 mm. beyond the extremity of the terminal segment. The posterior margin of the tergum of each thoracic somite, except the first, is curved backwards in the middle line into a short spine; these diminish in size from before backwards.

The pleural plates of the second abdominal segment are long and reach beyond the end of the terminal segment in the male, but not quite to the end in the female; those of the third abdominal segment are short and do not extend far down the terminal segment. The terminal segment is hexagonal in outline, its posterior end projecting as a short spine. It bears a median dorsal and two lateral keels, the latter starting from the base of a strong, stout spine, which lies in a median anterior position, and terminating in two short spines placed some distance in front of the bases of the uropoda. A transverse curved ridge, which is prolonged backwards into three short spines, the median one the larger, extends across the segment in a line with the terminal spines of the lateral keels.

REMARKS. Beddard (1884 *b*, p. 43) states that the antennules and antennae are of equal length and that "the antennae of the males possess a series of delicate lamellar processes (pl. ii, fig. 6) arranged in a single line along the inner side of most joints, being absent only from a few of the extreme distal and proximal joints". He also says that "the anterior margin of the middle joints has a series of short curved spines like those already described for *S. paradoxa*". I find on examination that the antenna of this species is considerably longer than the antennule, the latter only extending to the end of the peduncle of the former. I also find that there is only one set of spines on the flagellar joints of the antennae, and that these correspond with the "delicate lamellar processes" of Beddard's description. The spines are also present in the female, so that they can no longer be regarded as a secondary sexual character. These lamellar processes, which are present on the ventral surface of the joints, presumably correspond with the "short curved spines" of *S. paradoxa*; similar though somewhat smaller processes occur in *S. polaris*.

The maxillae are of the usual type, except that the inner articulating lobe is slightly broader than that of most species and bears seven pectinate setae instead of the more usual numbers of either two or four: the fixed lobe bears fourteen or fifteen of these setae.

The maxillipeds (Figs. 2 *b*, *c*) agree with Beddard's description except that the "small protuberance carrying three stoutish hairs", which he states (1884 *b*, p. 43) to occur on the summit of the terminal joint of the palp, appears to be an extra, very minute joint which articulates with the so-called terminal joint at its outer distal angle. This small joint which occurs in other species of the genus probably represents the vestigial fourth joint of the five-jointed palp of the ancestral type.

The thoracic appendages have been described already, but the form of the dactylus of the third appendage of the female and of the immature male, and of the fourth of the adult male appears to have been overlooked. The dactylus of these appendages (Fig. 4 *a*) is somewhat flattened, and bears, on the anterior edge of the distal third of its length, a series of curved though flattened spines which increase in size towards the extremity. Arising between the two most distal of the spines is a strong seta which is densely plumose, and three setae, the middle one of which is sparsely plumose, spring from a slight depression on the posterior margin. The dactylus of the other appendages is less flattened and never bears this row of spines, but a plumose seta (often broken), a couple of strong spines and a few setae may be present at its distal extremity. The dactylus of the seventh appendage in the male is shorter than in the female, recurved, bearing a number of hairs on its outer margin, whilst the propodus and carpus bear groups of strong setae on their inner margins.

The endopod of the fourth pleopod is bifid, with the inner branch prolonged for some distance beyond the outer, and with its rounded extremity fringed with delicate hairs. The exopod of the uropod is shorter than the endopod; the latter is broad, with its distal end obliquely truncated, and with the inner angle rounded and the outer pointed and slightly produced (Fig. 4 *b*).

Colour. Pale brown, becoming darker in the middle of the body, with dark brown or black spots which vary considerably in number and size in different specimens.

Distribution. From the Gulf of Peñas, in the north to the Falkland Islands in the south ('Challenger').

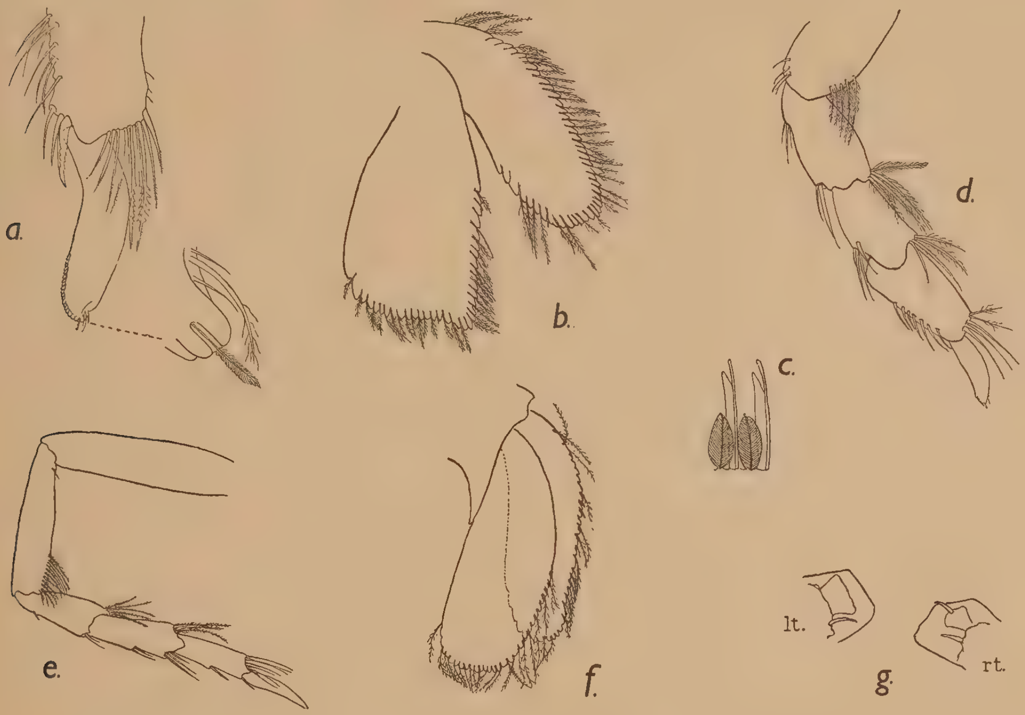

Fig. 4. *Serolis schythei*, Lütken, *S. polaris*, Richardson, and *S. glacialis*, Tattersall.

S. schythei, Lütken. *a*, dactylus of third thoracic appendage of ♀: × 20. *b*, uropod: × 20.

S. polaris, Richardson. *c*, type of setae on propodus of second thoracic appendage. *d*, third thoracic appendage of immature ♂. *e*, fifth thoracic appendage of ♂. *f*, uropod.

S. glacialis, Tattersall. *g*, cutting edges of mandible: × 42.

[Serolis serrei, Lucas.

S. serrei, Lucas, 1877, pp. cxlv, cxlvi; Beddard, 1884 *b*, p. 32.

This species has not been recorded since it was first briefly described by Lucas in 1877 from a collection made by the French vessel 'Magicienne' in the Strait of Magellan. The description given by Lucas is repeated in the Challenger Report (Beddard, p. 32).

According to Lucas the species is closely allied to *S. trilobitoides*. It measures 27 mm. in length and 36 mm. in breadth; its dorsal surface is covered with small brown spots, whilst the ventral surface and the surface of the limbs is of a yellow colour. The coxal plates are transparent and not serrated at their margins. The terminal segment is broader than long, rounded, ending posteriorly in a fairly large median acute spine; three carinae are present on its dorsal surface, and its lateral margins are not toothed.

Beddard (1884 *b*, p. 32) remarks: "it seems to me, from the above quoted description, that it is probably more nearly related to *Serolis schythei*". I agree with Beddard that this may be so. This view is supported by the fact that the distribution of *S. serrei* agrees with that of *S. schythei* and differs from that of *S. trilobitoides*. The description of the species is so brief that it is impossible to make any definite statement with regard to its exact systematic position.]

6. **Serolis polaris**, Richardson (Figs. 4 *c–f*; Plate XIV, fig. 2).

Serolis polaris, Richardson, 1911, pp 396–8, fig. 1; Nordenstam, 1933, p. 58.

DIAGNOSTIC CHARACTERS. This species was instituted to contain six specimens, all of which were said to be females. Through the kindness of Prof. Ch. Gravier, of the Museum d'Histoire Naturelle, I have been able to examine the type specimen and find that it is undoubtedly a male; for although it is immature the appendix masculina on the second pleopod is quite well developed. This specimen measures 19 mm. in length and 21 mm. in breadth. The measurements given by Richardson are presumably those of a female and are length 22 mm. and breadth 22 mm., so that as in so many species of this genus the male is broader in proportion to its length than is the female.

The head is broader than long, with its broadest portion on a level with the eyes, which lie in a posterior position just within the lateral margins. The eyes are reniform in shape and are less prominent and less deeply pigmented than those of *S. schythei*, Lütken.

The body (Plate XIV, fig. 2) bears a close resemblance to that of *S. schythei*, although it is slightly less flattened. As in that species the posterior margin of the free thoracic somites is produced backwards to form a small median spine, that of the fifth somite being the largest. The coxal plates of the free thoracic somites have their postero-lateral angles acutely produced backwards. The first four pairs are separated from their respective somites by sutures, and just within the suture, on either side, the tergum is raised into an angular prominence. The coxal plates of the seventh thoracic somite extend backwards to the postero-lateral angles of the terminal segment, the pleural plates of the second abdominal segment to the end of the terminal segment and those of the third segment to about the middle of the segment. The posterior margin of each of the abdominal segments is produced to form a median tooth similar to those of the thoracic somites.

The terminal segment is roughly hexagonal in outline, with both the anterior and the posterior angles very obtuse, and with the sides slightly converging and terminating in an acute tooth on either side, into the angle of which the protopodite of the uropod is inserted.

The dorsal surface is furnished on either side with a curving ridge, situated close to the anterior and lateral margins of the segment; behind this, arising from a small flat angular process, one on either side of the base of a large median spine, is a second ridge which runs obliquely outwards to terminate in an angular process near the postero-lateral angle of the segment. The median spine is long, prominent and acute, and is situated in the anterior part of the segment; behind it the median portion of the segment is slightly keeled, and a transverse curved ridge, produced into three acute, flat spines, one in the median line and one on either side, passes across the segment at the level of the angular process of the oblique ridge.

REMARKS. The appendages of this species have not been described; the following notes are based on observations made on the type specimen:

The antennule and the antenna have been described by Richardson (pp. 396–7), who, however, has not observed the structure of the flagellum of the antenna. As in *S. schythei*, Lütken, a series of delicate lamellar processes is arranged in a single row on the ventral surface, near the posterior margin of most of the joints—these processes are slightly smaller than those present in *S. schythei*.

The basipodite of the maxilliped is fused with the lamella as in *S. schythei* (Fig. 2 *b*): it was impossible to see whether or not the extra minute joint of the palp was present.

The second thoracic appendage is modified in the usual way; the propodus bears modified spines of the types shown in Fig. 4 *c*. The third appendage (Fig. 4 *d*) of this specimen has not developed the characters of the adult male. It is, however, stouter and shorter than the remaining thoracic appendages, and bears a row of toothed spines along the propodus; the dactylus is modified in a similar way to the corresponding appendage of *S. schythei* (Fig. 4 *a*). Long plumose setae, similar to those found on the pleopods, are present on the posterior border of the ischium and at the posterior distal angles of the merus and carpus of this and the remaining thoracic appendages (Fig. 5 *e*).

Each of the sternal plates of the first three abdominal segments has the median posterior border produced into a spine. The protopodite of each of the first three pairs of pleopods is characterized by the absence of plumose setae; in this they agree with *S. schythei* and *S. paradoxa*.

The suture of the exopod of the fourth pair is oblique and the distal extremity of the endopod is bifid, with the inner branch extended some distance beyond the outer; the endopod of the fifth pleopod has a rounded distal extremity.

The uropoda (Fig. 5, *f*) do not extend to the tip of the terminal segment; the exopod is shorter than the endopod, both are broadly rounded, toothed, and fringed with plumose setae.

DISTRIBUTION. South Sandwich Islands.

This species is undoubtedly very closely related to *S. schythei*, Lütken, and also to *S. paradoxa*, Fabricius. The following points result from a comparison of the three species:

(1) The males of *S. schythei* are proportionately broader than those of the other two species, whilst the body of the former is more flattened than that of the other two.

(2) The head of *S. polaris* and *S. schythei* is broadest at the level of the eyes, whilst that of *S. paradoxa* is broadest anteriorly. The eyes of *S. schythei* are larger than those of *S. polaris*.

(3) In all three species the first four free somites are separated by sutures from their

respective coxal plates; in *S. paradoxa* the position of the suture on the fifth free somite is indicated by the presence of a slight groove.

(4) In *S. polaris* the coxal plates of the seventh thoracic somite extend to the level of the bases of the uropoda, whilst the pleural plates of the second abdominal segment extend beyond them to the end of the terminal segment: the pleural plates of the third segment are a little shorter than the coxal plates of the seventh thoracic somite. In *S. schythei* the coxal plates of the seventh thoracic somite extend backwards for some distance beyond the end of the terminal segment, whilst the pleural plates of the second abdominal segment extend almost to the postero-lateral angle, and those of the third to just beyond the anterior margin of the terminal segment. In *S. paradoxa* the coxal plates of the seventh thoracic somite extend to about the middle of the terminal segment and the pleural plates of both the second and third abdominal segments are short, only just reaching beyond the anterior margin of the terminal segment.

(5) The terminal segment of both *S. schythei* and *S. polaris* is more or less hexagonal in outline, that of *S. paradoxa* is more triangular; the spines on the transverse ridge, which are present in the two former species, are much larger in *S. polaris* than in *S. schythei*. The transverse ridge which is situated near the anterior margin in both *S. polaris* and *S. paradoxa* is hardly seen in *S. schythei*. The large anterior median spine is present in all three species.

(6) The lamellar processes which occur on some of the joints of the flagellum of the antenna in *S. schythei* are present, only less well developed, in *S. polaris*. Their place is taken by strong spines in *S. paradoxa*.

(7) The modification of the form of the dactylus of the third appendage in the female and immature male and of the fourth appendage in the mature male is seen in both *S. schythei* and *S. polaris*.

(8) The setae on the thoracic appendages of *S. schythei* are either simple, or serrated or pectinate; those of *S. polaris* are either simple or plumose, like those on the pleopods. The setae on the thoracic appendages of *S. paradoxa* are like those of *S. schythei*, but in this species the inner margin of the ischium, merus and carpus of the third appendage of the adult male is fringed with delicate plumose setae.

From the above comparison it is obvious that the three species are quite distinct.

7. **Serolis glacialis**, Tattersall (Figs. 2 *d*, *e*, 4 *g*).

S. glacialis, Tattersall, 1921, p. 228, pl. vii, figs. 1–5; Monod, 1926, p. 35, figs. 33, 34.
S. glacialis, Tattersall, var. *austrogeorgiensis*, Nordenstam, 1933, p. 65, pl. i, fig. 1, text-fig. 16.

Occurrence. St. 180: Palmer Archipelago, 160–330 m.; 1 ♀ (b.).
St. 181: Palmer Archipelago, 160–335 m.; 4 ♂♂, 5 ♀♀ (b.)
St. 182: Palmer Archipelago, 278–500 m.; 2 ♀♀ (b.), 6 immature specimens.
St. 187: Palmer Archipelago, 259 m.; 1 ♀ (non-b.).

DIAGNOSTIC CHARACTERS. The body is broadly oval, slightly longer than broad, semi-translucent, especially laterally. The head is nearly twice as wide as long with a small rostral process between the bases of the antennules. Behind this process is a well-marked transverse ridge which extends laterally to the sides of the cephalosome, and between the anterior ends of the eyes is a second transverse ridge behind which is a deep groove. The portion of the head between the eyes is raised into three oval prominences, the posterior margins of which are more sharply defined than the anterior. The eyes are large, reniform, with black pigment.

Each of the third to the seventh thoracic somites is produced in the median dorsal line into a short but distinct spiniform process. The coxal plates are well developed and those of the first three free somites are separated by sutures; those of the seventh thoracic somite are produced backwards and extend about to the level of the basal joint of the uropoda. The pleural plates of the second abdominal segment extend backwards beyond, and those of the third abdominal segment as far as, the coxal plates of the seventh thoracic somite. The terminal segment is furnished with a well-developed spine in the anterior median line, followed by a median dorsal keel which extends to the extremity. On each side of the median keel there are two lateral oblique ones, terminating in small spines some distance from the lateral margins, which are slightly turned downwards.

REMARKS. The only specimens of this species previously recorded are two males, the type specimen described by Tattersall (1921) and a second one identified by Monod (1926). The present collection contains nineteen specimens, of which nine are adult females and four adult males; all these are smaller than the type specimen, which measures 17 mm. in length and 14·5 mm. in breadth. The largest male in this collection is only 12 mm. long and 10 mm. broad, and the largest female is 11 mm. long and 8 mm. broad.

The specimens agree with the description given for the type, but there appears to be a sexual difference in the number of joints present in the flagellum of the antennule; in the males the number of joints is twenty-eight, compared with thirty-five in the type, whilst in the females the number of joints is only sixteen. A similar sexual difference also occurs in *S. kempi*, n.sp., and *S. aspera*, n.sp.

The form of the cutting edges of the mandibles is shown in Fig. 4 *g*. The maxillula is of the usual type: the outer lobe bears ten stout curved spines, nine of which are toothed, whilst the tenth innermost one is more delicate and pectinate; the inner lobe is about two-thirds the length of the outer, and is somewhat expanded for a short distance behind its distal extremity; the latter bears a single short seta.

The maxilla bears two spines on its outer, three on its inner, and nine on its fixed lobe; these spines each possess a double row of short pectinations. The maxilliped (Fig. 2 *d*, *e*) belongs to the type in which the basipodite is separated from its lamella by a suture; the lamella is almost square with the angles of its distal extremity rounded. The sexual difference in the form of the coxal joint may be seen from the figures.

The thoracic appendages have been described and figured by Tattersall (1921, p. 229, pl. vii, figs. 2–5). The protopodite of each of the first three pleopods is triangular in shape, and the produced angle bears three long plumose setae on the first and two on each of the second and third pleopods. The suture of the exopod of the fourth pleopod is almost transverse and the endopod is rounded and undivided. The exopod of the fifth pleopod is also partially divided by a transverse suture which extends from its outer margin for about a third of its width: two plumose setae are present at its extremity. The endopod of the fifth pleopod is about the same size as the exopod and is undivided.

Distribution. The specimens in this collection come from the Palmer Archipelago, a locality on the opposite side of the Antarctic Continent and not so far south as that given by Tattersall for his type specimens. The latter were taken off Oates Land, 69° 43′ S, 163° 24′ E.

Since the above was written, Nordenstam (1933, p. 65) has described a new form of *S. glacialis*, a variety *austrogeorgiensis*. The description is based on a single young female which appears to differ from the main species. Of the ten points of difference noted between this variety and the typical form, only three seem to be of real diagnostic value, namely:

(1) The posterior angles of the coxal plates do not protrude freely.

(2) The distinct proximal spine in the middle line on the pleotelson is missing, and the lateral keels are not so marked as in the main species and do not terminate in spines.

(3) The pleura of the third abdominal segment reach as far back as those of the second abdominal segment.

Of these three, number (2) is the only one to which any real importance can be attached. In the female of the typical form the spines are perhaps not so pronounced as in the male, and the pleura of the second and third abdominal segments are much more nearly the same length; those of the third segment do not reach quite as far back as those of the second. Since the differences between the species and its variety are so slight, I have no hesitation in including the varietal name *austrogeorgiensis* in the synonymy of *S. glacialis*.

Nordenstam gives a figure of the maxilliped of the variety (p. 68, text-fig. 16) and states that he failed to find any suture between "the coxopodite and the proximal epipodite". I very much doubt the correctness of this statement since in typical *S. glacialis*, and in fact in all the known species of *Serolis*, a suture is present in this position.

8. **Serolis septemcarinata**, Miers.

S. quadricarinata, White, 1847, p. 106.

S. septemcarinata, Miers, 1875, p. 116; Miers, 1879, p. 206, pl. xi, fig. 3; Studer, 1884, p. 8; Beddard, 1884 *b*, p. 47, pl. ii, fig. 14, pl. viii, figs. 3–5; Pfeffer, 1887, p. 63, pl. ii, figs. 5, 6, pl. iii, figs. 1–26, pl. iv, fig. 6; Collinge, 1918, p. 74, pls. iii, iv, figs. 1–13; Tattersall, 1921, pp. 227–8; Monod, 1931, p. 26; Nordenstam, 1933, pp. 61–3, text-figs.

S. ovalis, Studer, 1879, p. 24, pl. iii, figs. 8–10.

Occurrence. St. 32: South Georgia, 91–225 m.; 2 ♀♀ (b.).
St. 39: South Georgia, 179–235 m.; 2 ♀♀ (b.), 5 immature specimens.
St. 45: South Georgia, 238–270 m.; 5 ♀♀ (b.), 1 ♂.
St. 456: Bouvet Island, 40–45 m.; 16 ♀♀ (b.), 14 ♂♂, a number of immature. Cumberland Bay, from kelp root washed up on the beach. 2 ♀♀ (b.).
St. MS 71: East Cumberland Bay, 110–60 m.; 1 ♀ (b.).

Diagnostic characters. Beddard (p. 47) points out that in this species the males differ from the females only in their greater size. In this collection the largest female is 13·5 mm. in length and 10·5 mm. in greatest breadth; it has a greater length than Beddard's largest male specimen which measured 13 mm. in length and 11 mm. in greatest breadth. From these facts it is clear that there is little difference in the size of the sexes, but the male is slightly broader in proportion to its length than the female.

The body is broadly ovate with a sculptured surface of minute anastomosing ridges; the surface of the head and the tergal portion of the segments is covered with minute scattered pits. The head is convex with a crescentic ridge in front of and between the eyes and a second ridge extending across the head close to its anterior margin: a small median rostrum is present. The eyes are placed in a postero-lateral position and are rather small, reniform in shape, and contain black pigment.

The thoracic somites are slightly convex and their coxal plates are compact; those of the third, fourth, and fifth are separated by sutures from their respective somites. The coxal plates of the seventh somite do not extend as far as the distal extremities of the pleural plates of the second abdominal segment; each pleural plate of the third segment extends slightly beyond that of the second to a point just beyond the distal end of the protopodite of the uropod.

The terminal segment ends in a trifid extremity; its dorsal surface is furnished with a median longitudinal carina, extending to its tip, and on either side of this are two lateral carinae which do not extend throughout the length of the segment but end in freely projecting spines. Close to the lateral margin of the segment, on each side, is another small carina which extends to a point just anterior to the base of the uropod.

Remarks. There is little to add to the already existing descriptions of this species except to point out that the last thoracic appendage of the adult male, as figured by Pfeffer (*loc. cit.*, pl. iii, fig. 21), does not show the presence of numerous fine hairs along the inner margins of the propodus and carpus and on the distal half of the merus. The presence of these hairs was noted by Beddard (1884 *b*, p. 49) and they are undoubtedly present.

Collinge (1918, p. 75, pl. iv, figs. 7, 9), in his description of this species, states that there is only one variety of sensory spine present on the inner margin of the propodus of the second thoracic appendage: this fact was noted as incorrect by Tattersall (1921, p. 228), who confirmed Pfeffer's observations that two types were present. My own observations agree with those of the two latter workers.

Distribution. The original material of Miers was collected off the Crozet Islands, Studer's and Collinge's specimens came from Kerguelen, and Tattersall's from Cumberland Bay, South Georgia. It is from this last locality that the specimens in the present collection were obtained.

9. **Serolis kempi**, n.sp. (Figs. 5, 6).

Occurrence. St. 388: 56° 19½′ S, 67° 09¾′ W, 121 m.; 3 ♂♂, 6 ♀♀ (b.), 7 immature.
St. WS 86: 53° 53′ 30″ S, 60° 34′ 30″ W, 151–147 m.; 2 ♂♂, 2 ♀♀ (b.), 2 ♀♀ (non-b.) and 3 immature specimens.
St. WS 244: 52° 00′ S, 62° 40′ W, 253–247 m.; 6 ♂♂, 13 ♀♀ (b.), 6 ♀♀ (non-b.), and 11 immature specimens.
St. WS 245: 52° 36′ S, 63° 40′ W, 304–290 m.; 1 ♂, 5 ♀♀ (b.), 33 immature specimens.
St. WS 795: 157–161 m.; 1 ♀ (b.).
St. WS 818: 52° 31′ 15″ S, 63° 25′ W, 272–278 m.; 1 ♀ (b.), 7 immature specimens.

Description. This collection contains adult males and females, the latter in both the breeding and non-breeding phase. An adult male measures 15 mm. in length and 14 mm. in breadth, and an adult female 15 mm. in length and 13 mm. in breadth.

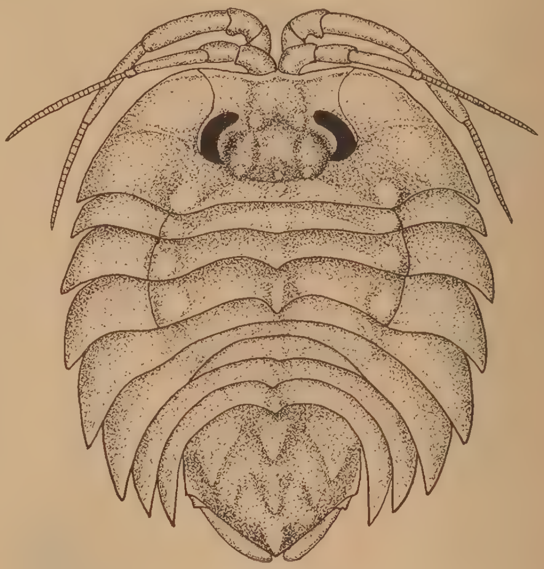
Fig. 5. *Serolis kempi*, n.sp., ♂: × 6.

The body (Fig. 5) is broadly oval, slightly longer than broad and slightly keeled. The head is about one and a half times as wide as long, shield-shaped in outline, with a very small rostral process between the bases of the antennules: behind this process a well-marked transverse ridge extends laterally to the sides of the cephalosome. The portion of the head between the eyes is convex and divided into two areas by a slight groove; an anterior one bearing two rounded prominences and a posterior larger one, divided into three oval prominences, the central of which is smaller than the two lateral: this area extends for some distance behind the eyes.

The eyes are large, about half the length of the head, reniform in shape and containing black pigment.

The second thoracic somite is fused with the head as in all the species of *Serolis*. The lateral portion bears two transverse ridges on each side, a small anterior one which is continuous with the anterior one already described on the head, and a second which extends laterally from near the posterior angle of the eye, a point about half-way between the anterior and the posterior margins of the cephalosome. Each of the third to the seventh thoracic somites is produced into a short but distinct median dorsal spiniform process; that of the fifth somite is considerably larger and longer than those of the other somites and projects backwards to about the middle of the sixth somite. Low eminences are present, one on either side of each of the thoracic somites, just within the junction of the tergum with its coxal plate. The coxal plates are well developed and are sparsely fringed with short hairs, those of the first three free somites are marked off by distinct sutures. The coxal plates of the seventh thoracic somite are produced backwards to a point a short distance behind the level of the bases of the uropoda.

The abdomen (Fig. 5) consists of three free somites and a terminal one, and each of the three somites has a slight median dorsal process corresponding with those of the thoracic somites. The pleural plates of the second segment are well produced backwards beyond the coxal plates of the seventh thoracic somite to about the level of the basal joint of the uropod; those of the third segment are longer and reach beyond the basal joint of the uropod. The terminal segment, which is broader than long, has a well-developed spine in the anterior median dorsal line; this is followed by a slight median keel which terminates in a second spine at some distance from the pointed and somewhat upturned posterior extremity of the segment. On each side of this median keel there are two lateral oblique ridges, each terminating in a spine some distance from the lateral margins of the segment; these latter are slightly turned downwards.

The antennule and the antenna are rather long, the latter being longer than the former and extending back to about the posterior margin of the second free thoracic somite. The first and second joints of the peduncle of the antennule are sub-equal, but the first is somewhat bow-shaped; the third joint is twice as long as the second and six times the length of the fourth. The flagellum consists of twenty-three joints in the male, but only seventeen in the female; the terminal joint is very small and bears a group of four stout hairs at its tip: an olfactory seta together with several simple setae are present at the distal end of each joint. The first joint of the peduncle of the antenna is short, the second and third are sub-equal, the fourth nearly twice as long as the second, and the fifth slightly longer than the fourth. Tufts of long setae are present on the outer border of the three distal joints, whilst a few shorter ones are scattered along their inner margins. The flagellum consists of seventeen joints, the terminal one of which is small and bears four delicate setae.

The mandibles are of the usual type: the form of the cutting edge of both the left and right mandible is shown in the figure (Fig. 6 *a*). The outer lobe of the maxillula bears,

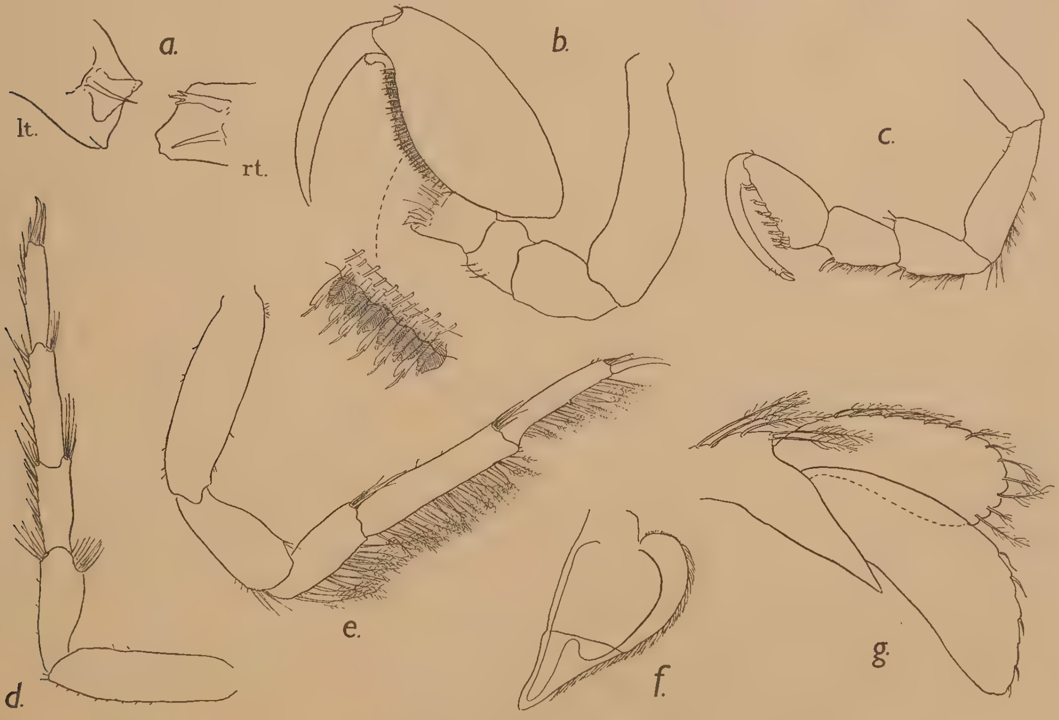

Fig. 6. *Serolis kempi*, n.sp.

a, cutting edges of mandible: × 24. *b*, second thoracic appendage of ♂: × 24. *c*, third thoracic appendage of adult ♂: × 24. *d*, fourth thoracic appendage: × 24. *e*, eighth thoracic appendage: × 24. *f*, fourth pleopod: × 15. *g*, uropod: × 30.

on its truncated distal extremity, ten simple spines and one pectinate seta, the latter being innermost in position. The inner lobe is slender and curved with a slightly broadened distal extremity on which may be found a single, very short seta. The fixed lobe of the maxilla has its rounded distal end fringed with about twenty pectinate setae; the distal end of the outer articulated lobe bears two, and that of the inner, four similar setae.

The basipodite of the maxilliped is not separated by a suture from its lamella; scattered setae are present on its outer surface. The inner margin of the basipodite is fringed with fine hairs and groups of these are also found on the outer margins of the lamella and the epipodite. A very minute extra joint is present near the outer distal end of the third joint of the palp and bears a number of setae on its truncate extremity (cf. *S. polita*, Pfeffer, *S. pagenstecheri*, Pfeffer, and *S. platygaster*, n.sp.).

The second, third and fourth thoracic appendages are shown in Figs. 6 *b–d*. The second appendage, as usual, is of stout build, with the propodus greatly expanded, having its outer distal angle somewhat pointed and its inner margin armed with a row of about thirty-eight broadly oval processes alternating with peculiar stout spines (Fig. 6 *b*). The distal edge of the carpus is crenulate and bears a number of simple setae as well as two stout spines, the upper halves of which are closely pectinate. The third thoracic appendage of the male (Fig. 6 *c*) is much more slender than the second. The propodus is broad at the base but tapers towards its distal end; it bears, on its inner margin, a double row of six spines of the usual type. The dactylus is longer than the propodus and ends distally in two strong spines; a few scattered setae occur along its outer margin, whilst a number of very short spines are also present along its inner margin. The inner margins of the carpus and merus are fringed with a dense mass of fine hairs scattered amongst which are a few long setae; these hairs extend for a short distance along the inner margin of the ischium. A further sexual difference in this species occurs in the last thoracic appendage of the adult male (Fig. 6 *e*), the inner margins of the merus, carpus and propodus are fringed with long plumose setae, whilst a group of three or four is also present at the outer distal extremity of the propodus. A similar sexual character has been described in *S. convexa*, Cunningham, *S. gaudichaudii*, Aud. et Edw., and *S. bouvieri*, Richardson.

Each of the three sternal plates of the abdominal segments in both sexes has the median posterior border slightly produced into a spine, increasing in length from the first to the third. The protopodite of each of the first three pairs of pleopods is not triangular in shape and does not bear any plumose setae. The exopod of the fourth pleopod (Fig. 6 *f*) is divided by a transverse suture at right angles to its long axis; the endopod is bifid at its distal end, and the inner branch is continued for some distance beyond the outer. The uropoda (Fig. 6 *g*) extend almost to the tip of the terminal segment; the basal joint of each is triangular with its inner distal angle prolonged into an acute spiniform process; its outer margin bears five long plumose setae. The exopod is shorter than the endopod and is fringed with plumose setae; the rounded distal extremity of the endopod bears a few short hairs.

Distribution. From 52° to 53° 53′ S, and 60° to 63° W, between the Falkland Islands and South America.

This species appears to be most closely related to *S. septemcarinata*, Miers, and *S. glacialis*, Tattersall. A comparison of these two species is included in the description of the latter by Tattersall (1921, pp. 229–30) and certain points of difference are noted.

I have compared *S. kempi* with specimens of these two species in the present collection and have noted the following points of difference:

(1) The body of *S. kempi* is broader in proportion to its length than in either of the other two species: it is also less flattened. *S. glacialis* is more flattened, less compact than *S. septemcarinata* and more transparent than either of the other two species.

(2) The eyes of *S. kempi* and *S. glacialis* are larger than in *S. septemcarinata.*

(3) In *S. kempi* and *S. glacialis* each of the thoracic and first three somites of the abdomen has the median dorsal posterior border produced into a spine-like process, which is absent in *S. septemcarinata.* The spine of the third free thoracic somite in *S. kempi* is much larger than any of the others and is also larger than the corresponding one in *S. glacialis*, whilst those of the abdomen are proportionately larger in *S. glacialis* than those of *S. kempi.*

(4) In *S. kempi* the coxal plates of the seventh thoracic segment do not extend backwards as far as the pleural plates of the second abdominal segment, and these in turn are shorter than those of the third abdominal segment. In *S. glacialis* the coxal plates of the seventh thoracic somite extend backwards as far as the pleural plates of the third abdominal segment and not quite as far as those of the second. In *S. septemcarinata* the coxal plates of the seventh thoracic somite are shorter than the pleural plates of the third abdominal segment, which in turn are slightly longer than or are equal to those of the second.

(5) In *S. kempi* the last segment of the abdomen bears anteriorly a prominent median dorsal spine; this is also present in *S. glacialis*, but is absent from *S. septemcarinata.* The median dorsal carina posterior to this spine extends to the tip of the segment in *S. glacialis*, but ends in a short spine at some distance from the tip in *S. kempi.* There are five dorsal carinae on this segment in both *S. kempi* and *S. glacialis* and seven on that of *S. septemcarinata.* The posterior extremity of the segment is keeled and upturned in *S. kempi*; it is trifid in *S. septemcarinata*, and is pointed in *S. glacialis.*

(6) There are certain sexual differences which are characteristic of these species. In *S. kempi* and *S. glacialis* the number of joints in the flagellum of the antennule is greater in the male than in the female. Hairs are present on the merus, carpus and propodus of the last thoracic appendages of the adult male of *S. kempi* and *S. septemcarinata*; these hairs are plumose in the former and simple in the latter species and are wanting in *S. glacialis.* A further sexual character peculiar to the adult male of *S. septemcarinata* is the development, on the ventral surface of the second thoracic somite, of a row of ridge-like tubercles, arranged in a semicircle with its convexity directed forwards and outwards, situated one on either side just external to the articulation of the appendage.

10. Serolis polita, Pfeffer.

S. polita, Pfeffer, 1887, p. 81, pl. ii, figs. 3, 4, pl. iv, fig. 4; Richardson, 1906 *a*, p. 7; Richardson, 1911, pp. 396; Tattersall, 1921, p. 231, pl. vii, fig. 6; Monod, 1931, pp. 26–7; Nordenstam, 1933, pp. 63–5, text-figs.

Occurrence. St. 371: South Sandwich Islands, 99–161 m.; 2 immature.
St. WS 25: South Georgia, 18–27 m.; 1 ♂ and 2 immature specimens.
St. MS 65: East Cumberland Bay, 78 m.; 1 immature specimen.
St. MS 66: East Cumberland Bay, 18 m.; 2 ♀♀ (b.), 2 ♀♀ (non-b.), 2 ♂♂, and 2 immature.
St. MS 67: East Cumberland Bay, 38 m.; 1 immature specimen.

DIAGNOSTIC CHARACTERS. The largest specimens, both male and female, measure 15·5 mm. in length; the male, as is usually the case, is broader than the female and measures 15 mm. in breadth; the breadth of the female is 13·5 mm. The body is broadly ovate and slightly keeled.

The head is broadest anteriorly; its margin is excavated for the reception of the antennules, between which it is produced forward as a very small rostrum. On either side of the head a transverse ridge extends from the outer side of the excavation for the antennule to the lateral margin of the cephalosome. The area of the head behind the rostrum is raised, and a short transverse ridge extends across between the anterior margins of the eyes; immediately behind this is a shallow depression. The area between the eyes is convex and divided into three areas, the two lateral of which appear as somewhat obliquely placed oval prominences. The central area is not raised as much as the lateral ones, neither does its straight posterior margin extend back as far: the posterior margins of these prominences are better defined than the anterior, which merge into the general surface of the head. The lateral portion of the second thoracic segment is not divided by a transverse ridge.

Eyes large, reniform in shape, containing black pigment.

The third and fourth thoracic somites are sub-equal, the fifth is slightly longer; the sixth and seventh are together equal in length to the fifth. In the mid-dorsal line each somite is produced into a small spiniform process. The coxal plates are well developed and those of the third, fourth and fifth somites are marked off by distinct sutures. The coxal plates of the seventh somite are only slightly more produced than those of the other somites and do not extend nearly as far backward as do the pleural plates of the second and third abdominal segments.

Each of the three free abdominal segments bears a short median dorsal spiniform process. The pleural plates of the second and third segments are broad; those of the third segment are produced backward to the level of the articulation of the uropoda, those of the second to a level a little over half-way between the tip of the coxal plate of the seventh thoracic somite and that of the pleural plate of the third abdominal segment.

The terminal segment is broader than long, with a well-developed spine in the anterior median dorsal line, followed by a median keel which extends to the extremity. On either side of this keel are two lateral oblique keels, the outer one of which is the longer; each terminates posteriorly in a small spine at some distance from the lateral margins, which are somewhat flattened. The posterior extremity of the segment is rounded. The uropods extend almost to the tip of the segment; both the endopod and exopod are elongate oval in shape and fringed with long plumose setae, the latter a little shorter than the former.

REMARKS. The mouth-parts of this species are quite typical. The maxilliped has the basipodite separated by a suture from its lamella. Previous workers have failed to notice the presence of a very minute extra joint to the palp of this appendage; it lies in a slight groove on the outer side of the third joint, and does not extend as far as its tip, and it carries on its truncate extremity a group of three or four long setae. A similar joint is found in a corresponding position on the maxillipeds of *S. kempi*, n.sp., as well as in some less closely allied species; in *S. septemcarinata*, Miers, its position is indicated by a notch at the distal extremity of the third joint which separates off, on the outer side of the joint, a group of three or four long setae.

The types of spines present on the propodus of the second thoracic appendage are very similar to those figured by *S. beddardi*, Calman (see Fig. 3 *b*). Those on the propodus of the third thoracic appendage of the male are unlike the typical variety. Each consists of a broad proximal portion, the central axis of which extends as an elongated slender projection surrounded at its base by a dense mass of short hairs; the central area between the rows of spines is toothed, and as Tattersall (1921, p. 228) pointed out, the inner margins of the merus and carpus of this limb are densely clothed with long plumose setae. The propodus of the last thoracic appendage in the male is much broader than is usual and bears a series of stout spines each of which carries a double row of short pectinations towards its distal extremity; the merus and carpus are also broader in proportion to their lengths than are the corresponding joints of the other limbs.

DISTRIBUTION. Pfeffer's and Tattersall's specimens came from South Georgia, as did the present ones; Richardson has recorded it from Booth-Wandal Island and from the South Sandwich group.

11. **Serolis elliptica**, n.sp. (Figs. 7, 8).

Occurrence. St. 56: East Falkland Island, 10½–16 m.; 1 immature specimen.
St. WS 243: 52° 00′ S, 62° 40′ W, 253–248 m.; 3 ♀♀ (b.).

DESCRIPTION. The largest specimen (Fig. 7) measures 6 mm. in length and 4 mm. in greatest breadth. The body, together with the broad almost terminal uropods, is oval in shape, with a convex rounded dorsal surface covered with microscopic rounded scales, arranged in alternating rows and overlapping like tiles on a roof. The head is considerably broader than long, equally broad at the anterior margin and at the level of the eyes, but narrower between these two regions. There is no rostrum, but a slight concavity exists on either side of the middle line for the reception of the base of the antennules, behind which is a low transverse ridge which extends across the head and on to the lateral portions of the cephalosome. The eyes, which are small, oval in shape, and contain black pigment, are situated far apart, on slightly raised areas in the postero-lateral angles of the head.

The second thoracic somite is fused with the head, but this fusion may not be quite complete anteriorly (Fig. 7). The remaining thoracic somites are very broad, and the coxal plates correspondingly short: those of the third, fourth and fifth somites are separated from them by sutures. The third, sixth, and seventh somites are sub-equal, the fourth and fifth slightly longer. The coxal plates of the seventh somite are not much more produced than those of the sixth, and extend backwards almost to the level of the base of the uropods.

The first three abdominal segments are sub-equal, not much narrower than the last thoracic somite. The pleural plates of the second and third segments are broad, and produced backwards beyond the coxal plates of the seventh thoracic somite; those of the second extend almost to the posterior end of the terminal segment, those of the third beyond it, reaching nearly to the level of the outer distal angle of the protopodite of the uropod. The terminal segment is about as broad as long. It is almost circular in outline, but with the postero-lateral regions slightly excavated for the reception of the uropods, so that the posterior extremity appears to be broadly rounded. A median dorsal carina is present and the outer margins of the coxal and pleural plates are fringed with delicate plumose setae.

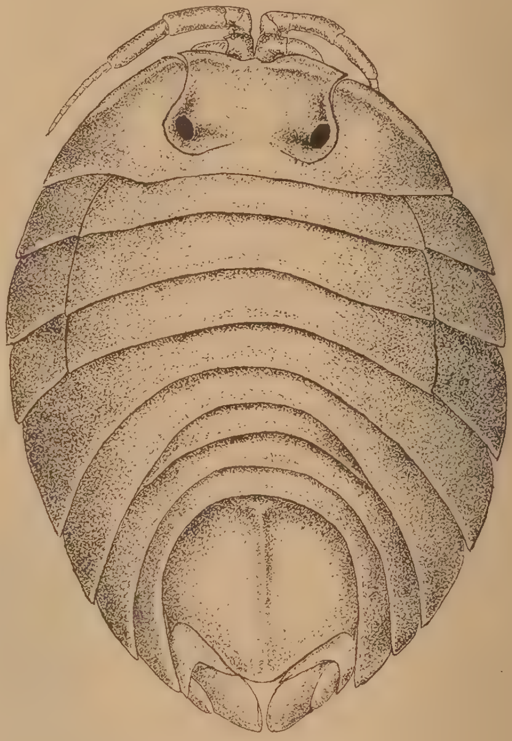
Fig. 7. *Serolis elliptica*, n.sp., ♀: × 22.

The antennule is short, about one-half the length of the antenna. The first peduncular joint is small; the second is twice as long as the first, broad, with rounded distal end; the third joint is the longest, but is narrower than the second; the fourth is a little shorter than the third. The flagellum consists of seven joints of which the terminal and penultimate are short, together equal to the fifth. A sensory seta is present at the tip of the terminal joint and at the anterior distal angle of the fourth, fifth and sixth joints.

The antenna consists of a peduncle of five and a flagellum of nine joints. The first peduncular joint is short, the second and third are a little longer: the inner margin of the second is fringed with short hairs and at its inner distal angle is a stout, densely plumose seta. The fourth and fifth joints are longer and sub-equal and their anterior margins bear groups of long setae between which is a fringe of shorter ones.

The mouth-parts are of the type usual in members of this genus. The primary cutting edge of the left mandible is rounded distally and slightly produced a little to one side of the middle; its secondary edge is in the form of two spines, one of which is slender, while the other is large and flattened distally to form a finely toothed blade. The primary edge of the right mandible is also rounded, with a single notch towards one side; the secondary edge again consists of two spines, a simple one, and a broad one which is flattened and notched at the distal extremity, but not as broad as the corresponding one on the left mandible.

The outer lobe of the maxillula bears eight strong spines and a single more delicate inner one on its truncate distal extremity. The maxilla is of the ordinary type, only its fixed lobe is not much broader than the articulating lobes: two long pectinate setae are present on each of the articulating lobes, and six on the fixed lobe.

The basipodite of the maxilliped is fused with the lamella as far as the articulation of the endopod: the lamella is broader than long, and fringed with short setae. The first joint of the endopod is short; the second is almost parallel-sided, expanding slightly at its distal end; the third is also parallel-sided, with a rounded tip bearing six setae. Setae are also present along the distal half of the inner margin of the second joint and two strong spines are present on the broad distal extremity of the endite.

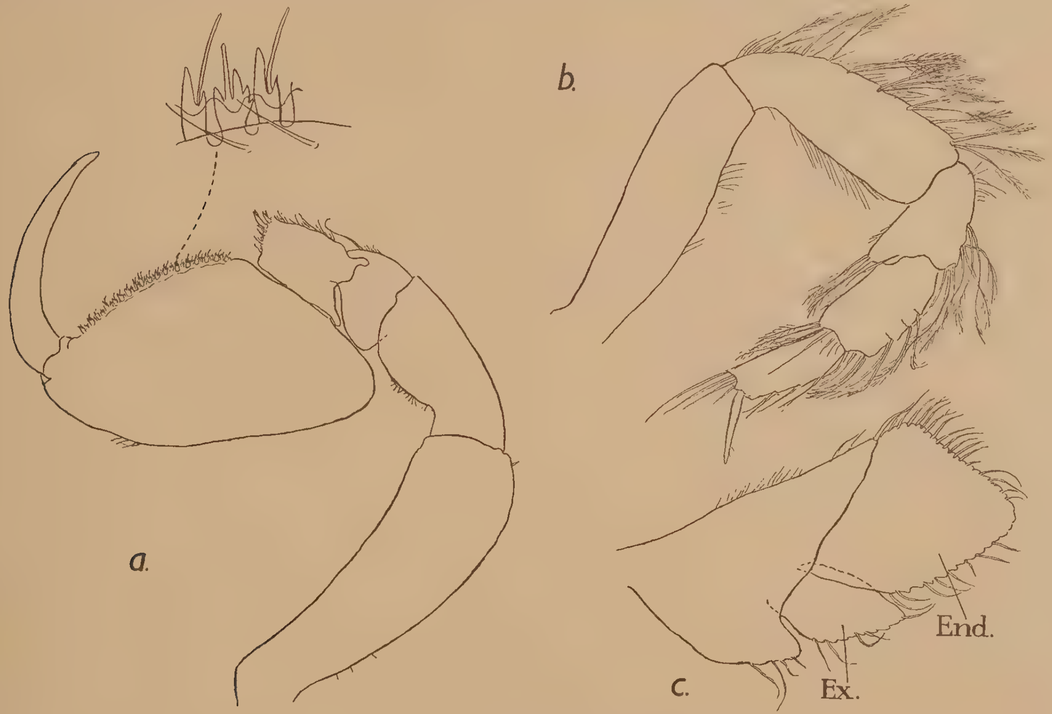

Fig. 8. *Serolis elliptica*, n.sp.
a, second thoracic appendage: × 70. *b*, fourth thoracic appendage of ♀: × 85. *c*, uropod: × 85.

The form of the second and fourth thoracic appendages is shown in Figs. 8 *a*, *b*. The second is stoutly built, with the propodus greatly expanded and with its inner margin armed with a row of about eighteen stout, modified spines, alternating with a peculiar toothed and broader variety (Fig. 8 *a*): the distal edge of the carpus is crenulate and bears two stout spines similar to, though smaller than, the longer variety of the propodus. The remaining thoracic appendages (Fig. 8 *b*) are all of approximately the same size: the last pair in this species is not smaller than the rest as it is in all other species of *Serolis*. Long plumose setae are present on the outer margins of the ischium, merus, carpus and propodus, whilst shorter pectinate setae are present at the distal ends of the carpus and propodus.

The protopodite of the first three pairs of pleopods is triangular with the produced angle bearing plumose setae—three on that of the first and two on each of the second and third. The suture of the exopod of the fourth pleopod is oblique, and its outer margin is sparsely fringed with setae; the endopod is rather small and broadly rounded distally.

The uropoda (Fig. 8 *c*) are short and broad, and meet beyond the distal end of the terminal segment. The protopodite has its inner angle produced into a broad triangular lobe, at the apex of which is a single plumose seta; the outer angle is also slightly produced and bears four delicate plumose setae on its outer margin. The endopod is not much longer than broad, about twice as wide as the exopod, with a short inner margin and with the distal portion broadly triangular in shape with rounded angles. The exopod, which is considerably smaller, is oval in shape, with its distal extremity rather pointed. The outer margin of the exopod, and the rounded distal end as well as the inner margin of the endopod, are fringed with delicate plumose setae.

12. **Serolis exigua**, Nordenstam (Figs. 2 *a*, 9, 10).

S. exigua, Nordenstam, 1933, pp. 70–5, pl. i, fig. 2, text-figs.

Occurrence. St. 51: East Falkland Island, 105–115 m.; 9 ♂♂, 6 ♀♀ (b.). St. WS 80: 50° 57′ S, 63° 37′ 30″ W, 152–156 m.; 2 ♀♀ (b.). St. WS 210: 50° 17′ S, 60° 06′ W, 161 m.; 2 ♀♀ (b.), a number of immature. St. WS 212: 49° 22′ S, 60° 10′ W, 242–249 m.; 1 ♀ (b.). St. WS 214: 48° 25′ S, 60° 40′ W, 208–219 m.; a large number of both ♂ and ♀. St. WS 215: 47° 37′ S, 60° 50′ W, 219–146 m.; 7 ♀♀ (b.), 1 immature. St. WS 216: 47° 37′ S, 60° 50′ W, 219–133 m.; 53 specimens, ♂ and ♀. St. WS 219: 47° 06′ S, 62° 12′ W, 116–114 m.; 4 ♂♂, 12 ♀♀ (b.). St. WS 220: 47° 56′ S, 62° 38′ W, 108–104 m.; 15 ♂♂, 11 ♀♀ (b.), a number of immature. St. WS 221: 48° 23′ S, 65° 10′ W, 76–91 m.; 2 ♂♂. St. WS 222: 48° 23′ S, 65° 00′ W, 100–106 m.; 1 ♀ (b.). St. WS 227: 51° 08′ S, 56° 50′ W, 295 m.; 3 ♀♀ (b.); St. WS 228: 50° 51′ S, 56° 58′ W, 229–236 m.; 1 ♀ (b.), 3 immature. St. WS 229: 50° 35′ S, 57° 20′ W, 210–271 m.; 2 ♀♀ (b.). St. WS 231: 50° 10′ S, 58° 42′ W, 167–159 m.; 1 ♀ (b.). St. WS 233: 49° 25′ S, 59° 45′ W, 185–175 m.; 1 ♀ (b.). St. WS 234: 48° 52′ S, 60° 25′ W, 195–207 m.; 3 ♀♀ (b.), 1 ♂. St. WS 236: 46° 55′ S, 60° 40′ W, 273–300 m.; a number of both ♂ and ♀ specimens. St. WS 237: 46° 00′ S, 60° 05′ W, 150–256 m.; a number of both ♂ and ♀ specimens. St. WS 243: 51° 06′ S, 64° 30′ W, 144–141 m.; 6 ♂♂, 15 ♀♀ (b.). St. WS 246: 52° 25′ S, 61° 00′ W, 267–208 m.; 10 ♀♀ (b.), 4 ♂♂. St. WS 766: 45° 13′ S, 59° 56′ 30″ W, 545 m.; a number of both ♂ and ♀ specimens. St. WS 773: 47° 28′ S, 60° 51′ W, 291–296 m.; 5 ♀♀ (b.), 1 ♂, several immature. St. WS 781: 50° 30′ S, 58° 50′ W, 148 m.; 1 ♀ (b.). St. WS 782: 50° 29′ 15″ S, 58° 23′ 45″ W, 141 m.; 11 ♂♂, 11 ♀♀ (b.), 5 immature. St. WS 786: 49° 07′ S, 63° 55′ W, 133–119 m.; 1 ♀ (b.), 7 immature. St. WS 787: 48° 44′ S, 65° 24′ 30″ W, 106–110 m.; 1 ♀ (b.). St. WS 795: 157–161 m.; 3 ♂♂, 1 ♀ (b.), 10 immature. St. WS 796: 47° 49′ 37″ S, 63° 42′ 30″ W, 106–113 m.; 1 ♂, 1 ♀ (b.). St. WS 801: 48° 26′ 15″ S, 61° 28′ W, 165 m.; 1 ♂, 1 ♀ (b.). St. WS 802: A, 50° 45′ 45″ S, 61° 22′ W, 128–132 m.; 1 ♂. St. WS 804: 50° 21′ 15″ S, 62° 53′ W, 143–150 m.; 1 ♀ (b.), 1 ♂. St. WS 805: 50° 10′ 15″ S, 63° 29′ W, 148 m.; 4 ♂♂, 1 ♀, 3 immature. St. WS 806: 50° 03′ 30″ S, 64° 21′ W, 129–122 m.; a number of both ♂ and ♀ specimens. St. WS 808: 49° 28′ 15″ S, 65° 42′ W, 109–107 m.; 1 ♀ (b.). St. WS 813: 51° 35′ 15″ S, 67° 16′ 15″ W, 106 m.; 24 ♂♂, 4 ♀♀ (b.), 9 immature. St. WS 814: 51° 45′ 15″ S, 66° 40′ W, 111–118 m.; 5 ♂♂, 4 ♀♀ (b.), 7 immature. St. WS 815: 51° 51′ 45″ S, 65° 44′ W, 132–162 m.; 4 ♂♂, 2 immature. St. WS 816: 52° 09′ 45″ S, 64° 56′ W, 150 m.; 1 ♂, 1 ♀ (b.). St. WS 818: 52° 31′ 15″ S, 63° 25′ W, 272–278 m.; 6 ♂♂, 1 ♀ (b.). St. WS 821: 52° 55′ 45″ S, 60° 55′ W, 461–468 m.; a number of both ♂ and ♀ specimens. St. WS 825: 50° 50′ S, 57° 15′ 15″ W, 135–144 m.; 4 ♀♀ (b.). St. WS 837: 52° 49′ 15″ S, 66° 28′ W, 98–102 m.; 5 ♀♀ (b.), 2 ♂♂, a number of immature. St. WS 864: 49° 33′ 30″ S, 64° 16′ W, 128–126 m.; 2 ♂♂. St. WS 866: 50° 37′ 45″ S, 64° 5′ W, 137–144 m.; 3 ♂♂, 1 ♀ (b.).

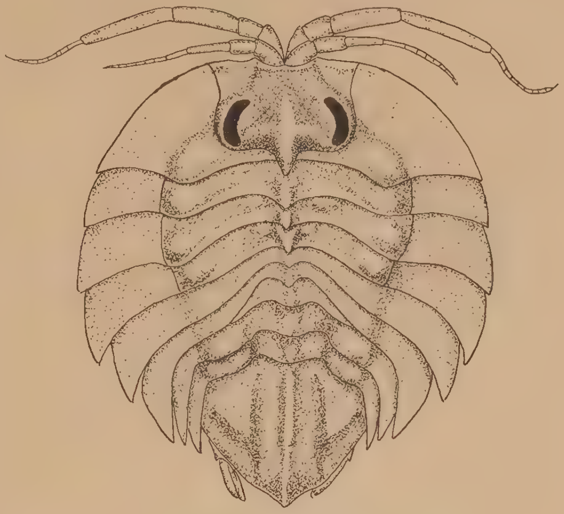

Fig. 9. *Serolis exigua*, Nordenstam, ♂: × 12.

Description. The body (Fig. 9) is broadly oval with a median keel; the male, the largest specimen of which measures 7·5 mm. in length and 6·25 mm. in greatest breadth, is slightly broader in proportion to its length than is the female: the latter measures 7 mm. in length and 5·5 mm. in breadth. The colour and markings of the body appear to be very variable.

The head is about twice as broad as long, shield-shaped in outline, with a narrow transverse ridge close to its anterior margin which extends laterally to the sides of the cephalosome. The portion of the head between the eyes is convex, with a strong median dorsal keel which is continued backwards as a spiniform process to about the middle of the third (first free) thoracic somite. The eyes are large, about half the length of the head, reniform in shape and containing black pigment.

Each of the third to the seventh thoracic somites has its posterior margin produced into a median dorsal spiniform process; those of the third, fourth and fifth somites are larger than those of the following somites, but are smaller than the corresponding process of the head: these processes are not so well developed in the female. The coxal plates of the third to the seventh thoracic somites are well developed, those of the third, fourth and fifth are separated from their respective somites by sutures. In the male the coxal plates of the seventh thoracic somite do not extend backwards quite as far as the pleural plates of the second abdominal segment; in the female they are considerably shorter.

The abdomen (Fig. 9) consists of three free segments and a large terminal one; each of the three free segments is slightly keeled and has a short median dorsal spine corresponding with those of the thoracic somites. The pleural plates of the third abdominal segment extend backwards beyond those of the second to a point level with the base of the uropod; the outer margins of both the coxal and pleural plates are sparsely fringed with hairs and short hairs are also present on their posterior margins.

The terminal segment is roughly five-sided, with the angles rounded. A median dorsal keel extends to the posterior extremity of the segment, but is more pronounced in the anterior half. On either side of this keel, lying midway between it and the lateral margin of the segment, is a lateral carina which extends nearly to the posterior margin of the segment; a secondary carina arises half-way along each of the lateral carinae and passes forwards and outwards to the lateral margin of the segment.

The antennule (Fig. 9) is very delicate, and consists of a peduncle of four joints and a flagellum of eight; the first peduncular joint is broad and geniculate, the second sub-equal to it, the third about twice as long as the second, but narrower, the fourth about a third the length of the third. The flagellum is slightly shorter than the peduncle; the first six joints are sub-equal, shorter than the fourth peduncular joint; the seventh flagellar joint is very short and about half the width of the sixth. The terminal joint is very narrow, but about equal in length to the sixth, with four delicate setae at its distal extremity. An olfactory seta is present at the distal end of each of the joints of the flagellum except the first two and the terminal one. The antenna is nearly twice as long as the antennule and consists of a peduncle of five and a flagellum of ten joints. The first peduncular joint is very short. The second and third longer and sub-equal, the fourth almost twice, and the fifth two and a half times as long as the third. The anterior borders of the third, fourth and fifth joints bear a series of tufts of long hairs. The flagellum is about equal in length to the fifth joint of the peduncle.

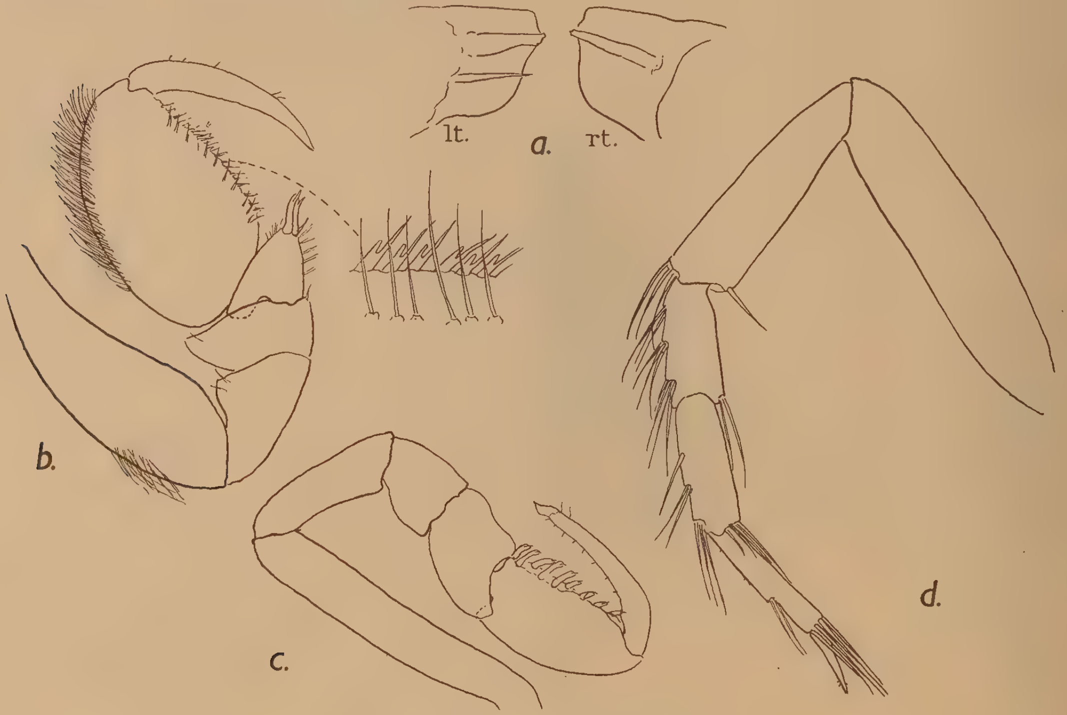

Fig. 10. *Serolis exigua*, Nordenstam.

a, cutting edges of mandible: × 55. *b*, second thoracic appendage of adult ♂: × 55. *c*, third thoracic appendage of adult ♂: × 55. *d*, fourth thoracic appendage: × 55.

The mandibles are of the ordinary type; the cutting edges are comparatively simple and of the form shown in Fig. 10 *a*.

The outer lobe of the maxillula bears eight spines and one delicate seta on its distal truncate extremity. The inner lobe is about half the length of the outer, with its distal end somewhat expanded and bearing a single, short curved seta with a bifid extremity. There are two pectinate setae on each of the two outer lobes of the maxilla, and eight pectinate and four simple setae on the rounded end of the fixed lobe.

The maxilliped (Fig. 2 *a*) has the basipodite completely fused with the lamella, the fusion being continued beyond the attachment of the basal joint of the endopod, so that the latter appears to spring from the centre of a plate-like structure. A similar arrangement occurs in *S. carinata*, Lockington.

The second, third and fourth thoracic appendages of the male are shown in Figs. 10 *b–d*. The propodus of the second appendage is broadly oval with its inner margin armed with a row of about thirty short stout spines: these spines (Fig. 10 *b*) are inclined slightly backwards, and each consists of two branches the posterior one of which is the longer; a series of rather long setae flank this row on either side. This and *S. nototropis*, n.sp., are the only species in which the propodus bears only one variety of modified spine on its inner margin; for although Collinge (p. 75) failed to find more than one type in *S. septemcarinata*, Miers, the observations of Beddard, Hodgson and Tattersall on this species show that in reality there are two. Another character peculiar to this species is the presence, in the adult male, of a dense covering of long delicate hairs on the outer distal part of the propodus of this appendage. The distal truncate end of the carpus bears two stout spines, each with a bifid extremity, and a number of simple setae. The third thoracic appendage of the male (Fig. 10 *c*) is considerably longer though more delicate than the second. The propodus is only slightly broader than the carpus; it has eleven spines of the usual type on its inner margin, arranged in three rows—two lateral ones of four spines each, three of which are placed near the proximal and one near the distal end of the propodus, and a median row of three, placed in a position intermediate between the distal and the proximal spines of the lateral rows. The dactylus terminates in a stout spine, the tip of which is slightly curved outwards. The last pair of thoracic appendages is shorter and more delicate than the others.

In each of the three sternal plates of the abdominal segments in both sexes the median posterior border is produced into a spine which increases in size from before backwards. The protopodite of the first three pairs of pleopods is somewhat triangular, with the produced angle bearing three plumose setae on the first, and two on each of the second and third pleopods. The appendix masculina on the second pleopod of the male reaches about two-thirds of the way towards the apex of the terminal segment. The exopod of the fourth pleopod has a transverse suture and a fringe of plumose setae along its outer margin; the endopod is entire and with a transverse suture.

The uropoda extend nearly to the tip of the terminal segment. The protopodite, as usual, has its inner distal extremity drawn out into a spine and the endopod is slightly longer than the exopod; both have rounded distal ends, crenate and fringed with plumose setae.

DISTRIBUTION. Off East Falkland Island, and between 66° and 58° W and 52° 55′ S.

This species appears to be most nearly related to *S. carinata*, Lockington, to which it bears a fairly close resemblance. The following points are noted after comparison of the two species:

(1) Both species are of small size, the adult males measuring not more than 8 mm. in length; the shape of the body is broadly oval with a median dorsal keel.

(2) Each of the thoracic and first three abdominal segments has the median dorsal posterior border produced into a spiniform process, which is much larger in *S. exigua* than in *S. carinata.*

(3) The median posterior border of the head is also produced into a spiniform process in both species; but in *S. carinata* this process is very small and does not extend beyond the head segment, whereas in *S. exigua* it is produced backwards to about the middle of the third (first free) thoracic somite.

(4) In both species the first three free thoracic somites are separated from their coxal plates by sutures. In *S. carinata* the coxal plates of the seventh thoracic somite extend beyond the ends of the pleural plates, which are very short and hardly extend beyond the anterior margin of the terminal segment. In *S. exigua* they are short and do not extend beyond the pleural plates of the second and third abdominal segments. The pleural plates of the third abdominal segment in *S. exigua* reach to the attachment of the uropod; those of the second are a little shorter.

(5) The terminal segment of *S. exigua* is broader than long and roughly five-sided, with a median dorsal and two lateral carinae, the latter lying midway between the median carina and the lateral margin of the terminal segment, and not extending to the posterior end of the segment. The terminal segment of *S. carinata* is roughly triangular, longer than broad, with its posterior extremity truncate, and with a median and two less pronounced lateral carinae which run parallel with the lateral margins of the segment and meet the central one at the posterior extremity.

(6) The antennules of both species are small, with a flagellum of ten or eight joints; the antennae are nearly twice as long, with short flagella.

(7) The maxillipeds of both species agree in having the basipodite fused with the lamella to a point beyond the attachment of the endopod, so that the latter appears to spring from the centre of a plate-like structure.

(8) The characters of the spines on the propodus of the second thoracic appendage of the two species differ. In *S. exigua* only one variety of spine is found, whilst in *S. carinata* two types are present, one of which is peculiar to the species. The propodus in the adult male of *S. exigua* is further characterized by the presence of long delicate hairs on its outer border; these are not found in *S. carinata.*

The above description was written before receiving Nordenstam's paper (1933). It agrees with that given by Nordenstam for *S. exigua* and his specific name has therefore been used. Nordenstam's description is based on the female only: in the above description the male characteristics are also included.

13. **Serolis carinata**, Lockington (Fig. 11).

S. carinata, Lockington, 1877, pt. 1, p. 36; Richardson, 1899, p. 842; Richardson, 1900, p. 224; Richardson, 1905, p. 321, figs. 353, 354.

I have been able to examine specimens of both sexes of this species through the generosity of Dr Waldo Schmitt of the United States National Museum, Washington, to whom I wish to express my gratitude. Neither the description nor the figures given in Richardson's *Isopods of North America* (1905) agree with my own observations, and for this reason I include here a revised account of the species.

DESCRIPTION. The body of the female is broadly ovate with a pronounced median dorsal carina: the coxal plates are much flattened. The male is slightly broader in proportion to its length than the female, and measures 8 mm. in length and 7 mm. in greatest width; the female is only 5·5 mm. long and 4·25 mm. wide.

The head is about as broad as long, with the anterior margin excavated on either side of a small median rostrum for the reception of the antennules. Just within the anterior margin, and running parallel with it, is a shallow transverse groove, behind which the area of the head between the eyes becomes raised. The central portion of this area, which is separated from the postero-lateral parts by slight grooves, is somewhat triangular in shape, with the apex directed backwards and terminating in a small spiniform process at the posterior margin of the head. At about the level of the middle of the eyes this area is raised to form a second small median process. The eyes, which are situated in postero-lateral positions on the head, are comparatively large, reniform in shape (not oval as stated by Richardson) and contain black pigment.

The lateral portion of the second thoracic somite, which is fused with the head, is broad and flattened, without any transverse ridges. The third, fourth and fifth thoracic somites are sub-equal, with the median keel produced backwards as a short spine; the sixth and seventh somites are short, their length together equal to less than that of those preceding them. Coxal plates well developed; those of the third to fifth somites marked off by distinct sutures, and *not* "perfectly coalesced, with no indication of the place of fusion" (Richardson, 1905, p. 322). Those of the seventh somite are produced backwards, but do not reach as far as the level of the base of the uropoda.

The abdomen is composed of three free somites and a large terminal one. Each of the free somites is keeled and bears a short median spiniform process. The process on the third segment is not on the posterior margin, but on a well-marked transverse ridge which extends across the segment, disappearing laterally on the pleural plates: this ridge lies a short distance within the posterior margin. The pleural plates of the second and third abdominal segments do not extend beyond the anterior margin of the terminal segment; those of the third segment are slightly the longer. The terminal segment is large, somewhat triangular in shape. In the female the apex is obtusely rounded, but not nearly as truncate as shown in Richardson's figure (1905, p. 321, fig. 353). In the male specimen in my possession the distal extremity is broader than that of the female and is slightly concave. A median and two lateral carinae are present; each of the latter runs parallel, one on either side, with the lateral margin of the segment, but at some distance within it, meeting the median carina at its posterior extremity.

The sterna of the three free abdominal segments are produced backwards to form median spines; in the female that of the first segment is much longer than those of the other two, extending almost to the tip of the second; in the male they are all of approximately equal size.

In the antennule the first peduncular joint is broad, rounded and geniculate; the second is about the same length only narrower; the third and fourth sub-equal, longer than the second. The flagellum consists of ten joints in the male and five in the female; the first joint is short, the second more than twice as long as the first, the remaining segments gradually decreasing in length and breadth to the penultimate one; the terminal segment is very small, bearing a sensory and two long simple setae. A single sensory seta is present at the distal end of each flagellar joint. In the antenna the peduncular joints are covered with microscopic imbricating scales, those of the fourth and fifth joints larger than those of the other joints. The first peduncular joint is short, the second twice as long as the first, both with fine hairs on their anterior margins; the third is about equal in length to the second, but not as broad; the fourth joint is a little more than twice the length of the third, its anterior margin bearing four groups of delicate setae on slightly raised areas at points about equidistant one from the other; the fifth joint is about one and a half times the length of the fourth, with a similar arrangement of setae. The flagellum is composed of seven joints, of which the first is the longest and broadest; the terminal and penultimate joints are very small, together equal to about a third of the length of the preceding one. Each joint is furnished with a short toothed spine at its distal posterior angle and a few delicate setae at its anterior angle.

Richardson's figures (1905, p. 321, fig. 354 *b*, *c*) of the maxillula and maxilla are quite inaccurate: she shows only one distal lobe in the former and two in the latter appendage, with none of the basal joints. Actually these appendages have the normal Isopod structure (see Figs. 1 *a*, *c*).

The maxillula has eight curved setae on the truncate distal extremity of the outer lobe; the inner lobe is delicate, about two-thirds the length of the outer, curved outwards towards its distal end and with a single short seta. The maxilla has the usual two setae on the distal ends of each of the two outer lobes, and seven or eight on the fixed lobe.

The lamella of the maxilliped (Fig. 11 *a*) is not separated from the basipodite by a suture, the union of the two extending beyond the articulation of the endopod, so that the latter appears to spring from the centre of a plate-like structure. Such an arrangement occurs also in *S. exigua*, Nordenstam (Fig. 2 *a*), *S. orbiculata*, n.sp. and *S. nototropis*, n.sp. The endopod is composed of three joints; the second is long and narrow with its distal angle somewhat produced, rounded, and bearing six setae; the terminal segment has six setae on its rounded distal extremity.

The cutting edges of the mandibles are simple, each with its distal extremity notched to form three large rounded teeth. In the three-jointed palp the terminal joint is rather short, with setae of the usual type on its posterior margin, and on that of the second joint.

The second, third and fourth thoracic appendages of the male are shown in Figs. 11 *b–d*. The propodus of the second is greatly expanded, with its inner margin armed with a row of twenty-three broad, leaf-like, toothed processes (Fig. 11 *b*), alternating with peculiar spines. The leaf-like processes are not unlike those found in a similar position in *S. elliptica*, n.sp. The distal end of the carpus is crenulate, and bears two strong modified spines (Fig. 12 *b*) as well as two or three more delicate ones. The third appendage of the male (Fig. 11 *c*) is considerably longer and more delicate than the second, with the propodus broad and bearing on its inner margin a double row of eleven spines of the type usually found on this limb. The last thoracic appendage is smaller than the others and is not modified in the male.

The protopodite of the first three pairs of pleopods is long, without a produced angle, and with the outer margin fringed with delicate hairs. Both exopod and endopod are fringed with strong plumose setae. The exopod of the fourth pleopod has an oblique suture, and the outer margin fringed with plumose setae; the endopod is rounded with a transverse suture. The uropoda extend to the tip of the terminal segment, with the inner distal angle of the protopodite produced and bearing three plumose setae. The exopod and endopod are sub-equal, with rounded distal extremities bearing plumose setae which also extend along their outer margins.

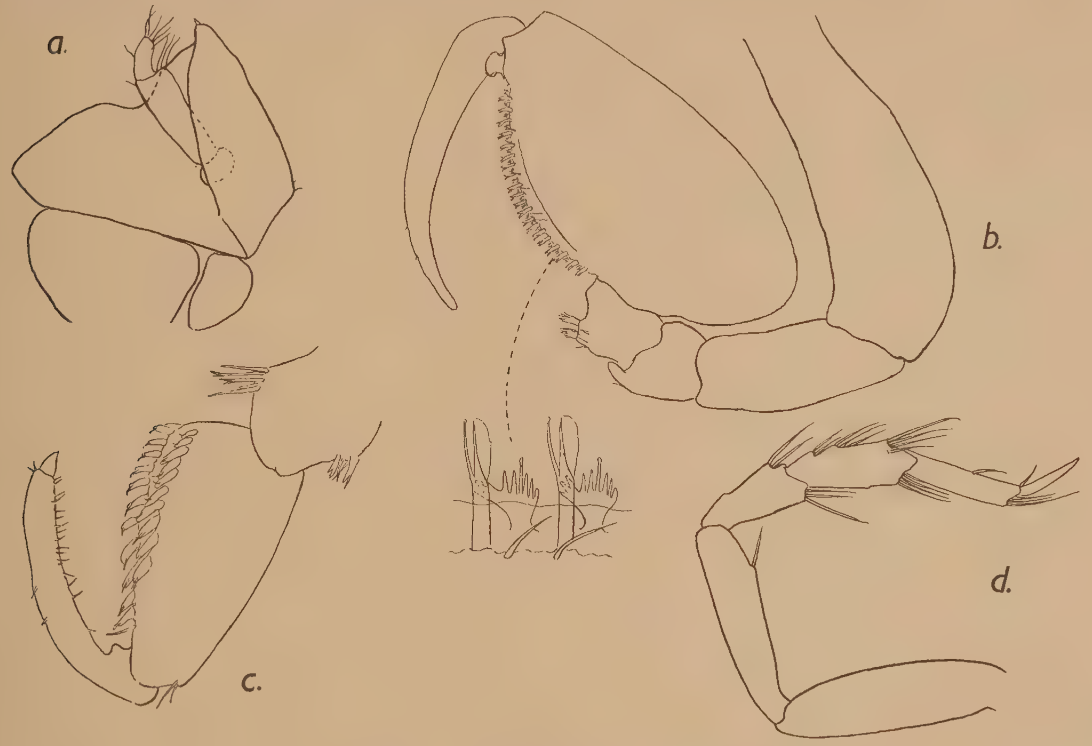

Fig. 11. *Serolis carinata*, Lockington.

a, maxilliped of ♂: × 52. *b*, second thoracic appendage of ♂: × 52. *c*, propodus and dactylus of third thoracic appendage of adult ♂: × 52. *d*, fourth thoracic appendage: × 35.

Locality. San Diego, California.

14. Serolis convexa, Cunningham (Fig. 12; Plate XIV, fig. 3).

S. convexa, Cunningham, 1871, p. 498, pl. lix, fig. 3; Studer, 1884, p. 9, pl. i, figs. 1 *a*, *d*; Beddard, 1884 *b*, p. 37, pl. vi, figs. 9–15; Nordenstam, 1933, pp. 77–82, text-figs.

Occurrence. St. 51: East Falkland Island, 115 m.; 1 ♀ (b.), 4 immature. St. WS 75: 51° 01′ 30″ S, 60° 31′ W, 72 m.; 2 ♂♂, 2 immature. St. WS 90: 13 miles N 83° E of Virgins Light, Argentine Republic, 82–81 m.; 1 ♂. St. WS 220: 47° 56′ S, 62° 38′ W, 108–104 m.; 2 immature. St. WS 222: 48° 23′ S, 65° 00′ W, 100–106 m.; 1 ♀ (b.), 3 immature. St. WS 787: 48° 44′ S, 65° 24′ 30″ W, 106–110 m.; 2 ♀♀ (b.), a number immature. St. WS 796: 47° 49′ 37″ S, 63° 42′ 30″ W, 106–113 m.; 1 ♂, 2 ♀♀ (b.), 3 immature. St. WS 797: 47° 45′ 36″ S, 64° 20′ W, 115–111 m.; 2 ♂♂ (young). St. WS 808: 48° 28′ 15″ S, 65° 42′ W, 109–107 m.; 1 ♂, 11 ♀♀ (b.), a number immature. St. WS 811: 51° 24′ 30″ S, 67° 53′ W, 96–98 m.; 1 ♀ (b.). St. WS 813: 51° 35′ 15″ S, 67° 16′ 15″ W, 106 m.; 1 ♂. St. WS 814: 51° 45′ 15″ S, 66° 40′ W, 111–118 m.; 1 ♀ (non-b.). St. WS 815: 51° 51′ 45″ S, 65° 44′ W, 132–162 m.; 1 immature specimen.

DIAGNOSTIC CHARACTERS. The body (Plate XIV, fig. 3) is pear-shaped owing to the comparatively long terminal segment, and to the fact that the sixth and seventh thoracic somites with their coxal plates are narrower than the preceding ones: the colour of the body is a uniform pale brown. The largest male in this collection measures 31 mm. in length and 24 mm. in greatest breadth, and the largest female 22 mm. in length and 17 mm. in breadth.

The head is slightly broader than long, broadest anteriorly, with a median rostrum behind which a transverse ridge extends laterally to the sides of the cephalosome. The eyes are reniform in shape, small but prominent, situated on raised areas placed rather near together. The median portion of the head, behind but between the eyes, is slightly raised and produced posteriorly into a small median spiniform process.

The dorsal surface of the body is convex with a median carina which in the fourth and fifth thoracic somites and in the three abdominal segments is produced backwards as a small spiniform process. The coxal plates of each of the first three thoracic somites are separated from their respective somites by sutures. The sixth and seventh somites are narrow and together equal to the fifth; the coxal plates of the seventh do not extend backwards as far as the middle of the terminal segment. The pleural plates of the second and third abdominal segments are short, not extending beyond the anterior margin of the terminal segment; those of the third are slightly the longer.

The terminal segment is roughly five-sided with a rather pointed posterior extremity. On its dorsal surface are a median and two lateral carinae; the latter are curved and follow the lateral margin of the segment, but at some distance from it, and each ends in a short spiniform process just anterior to the point of articulation of the uropod. The median carina is found in the anterior part of the segment and also towards its posterior extremity, the middle part being obsolete.

REMARKS. Beddard (1884 *b*, p. 37) describes a patch of plumose setae on the sternum of each of the last three thoracic somites as a sexual character peculiar to the males, and mentions that a small tuft may also be found on some of the others. This patch is present, however, on each of the sterna of the third to the seventh somites, that of the fourth measuring in a large specimen as much as 4 mm. in width. The patch is absent from the sterna of young males, apparently appearing along with certain other characters when the final moult to the adult stage is reached.

The appendages of this species have already been described, but some further observations are noted here. The mouth-parts are of the typical form, that of the cutting edges of the mandibles is shown in Fig. 12 *a*. The outer lobe of the maxillula bears on its truncate distal extremity nine simple spines and one pectinate seta having a bifid extremity; the inner lobe is delicate, about two-thirds the length of the outer, with its distal half bent outwards, and with its distal end only slightly expanded and bearing a single short seta.

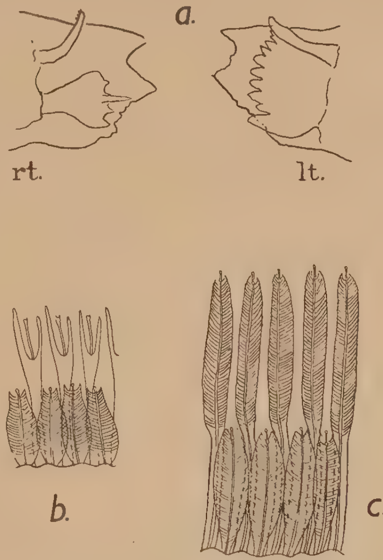

Fig. 12. *Serolis convexa*, Cunningham. *a*, cutting edges of mandible: × 40. *b*, form of spines on propodus of second thoracic appendage of ♀: × 40. *c*, form of spines on propodus of second thoracic appendage of ♂: × 40.

The maxilla is figured by Beddard (1884 *b*, pl. vi, fig. 14), but the sutures which correspond with those already described and figured in the introductory part of this paper are not shown. The fixed lobe is not much larger than the other two, each of which bears eight or nine pectinate setae instead of the more usual number of two.

The form of the spines on the propodus of the second thoracic appendage of the adult male is shown in Fig. 12*c*; according to Beddard (1884 *b*, p. 40) only a single row of short hairs is present on the distal portion of the longer variety of spines: as he points out, a tuft of long plumose hairs is present on the carpus of this limb. In examining the material of this collection, I have observed for the first time that in this species there is a sexual difference in the form of the modified spines on the propodus of the second thoracic appendage. In the female, and also in the immature male, as in the male, two kinds of spines are present in an alternating row, and those of the shorter variety are very similar in both cases. But in the immature male and in the female the longer variety (Fig. 12 *b*) consists of a spine expanding distally into two processes, one of which is a little longer and broader than the other; between these the central axis is continued as a third arm to about the level of the shorter of the two processes, where it ends in a bifid extremity. A similar condition also occurs in *S. gaudichaudii*, Aud. et Edw., and probably in *S. laevis*, Richardson.

The distribution of plumose setae in Beddard's figure of the last thoracic appendage of the male is incorrect; he figures them on the posterior margins of the ischium, merus and carpus, but actually they occur on the merus, carpus and propodus. Incidentally, he refers to this appendage in the text as the "sixth" instead of the last or eighth.

Distribution. The type locality for this species is the north coast of Tierra del Fuego; Beddard's material was collected at Port William, Falkland Islands. The material in this collection comes from off East Falkland Island and the Argentine Republic.

[**Serolis plana**, Dana.

S. plana, Dana, 1853, pt. ii, p. 794; Beddard, 1884 *b*, p. 39.

This species has not been recorded since it was described by Dana in 1853. Beddard (1884 *b*, p. 39) points out that it appears to be identical with *S. convexa*, Cunningham, except that the eyes are stated by Dana to be conical in shape, whereas in *S. convexa*, as in all the species of the genus, they are reniform.

The eyes of *S. convexa* are raised on prominences which might be described as conical, and it is possible that Dana was referring to the shape of these rather than to that of the eye itself—in which case the two species are identical.

LOCALITY. Patagonia, in a few fathoms.]

15. **Serolis gaudichaudii**, Aud. et Edw. (Plate XIV, fig. 4).

S. gaudichaudii, Audouin and Milne-Edwards, 1841, p. 5, pls. i, ii; Beddard, 1884 *b*, p. 38; Nordenstam, 1933, pp. 76–77, text-figs. 3*e–g*.

Occurrence. St. WS 221: 48° 23′ S, 65° 10′ W, 76–91 m.; 1 ♀ (b.).
St. WS 742: 38° 22′ S, 73° 41′ W, 47–35 m.; 1 ♂ (young), 3 ♀♀.
St. WS 809: 49° 28′ 15″ S, 66° 29′ W, 107–104 m.; 3 immature.
St. WS 856: 46° 45′ S, 64° 11′ W, 104 m.; a number of immature specimens.

DIAGNOSTIC CHARACTERS. The largest specimen in the collection (Plate XIV, fig. 4) measures 23 mm. in length and 17·5 mm. in breadth; it is approximately the same size as an adult female of *S. convexa*, Cunningham, to which species it bears a very close resemblance. The body, however, is more oval in shape, the decrease in width of the thoracic somites being gradual: that is, the sixth and seventh somites are not considerably narrower than the preceding ones as they are in *S. convexa*. The dorsal surface is less convex than in *S. convexa* and a median keel is hardly discernible.

The head, as in *S. convexa*, is slightly broader than long with its broadest part anterior; a median rostrum is present, behind which is a transverse ridge extending laterally to the margins of the cephalosome. The eyes are raised on two postero-lateral rounded prominences, between which the area of the head is sunken; behind the eyes the median area is slightly raised. The body colour is brown, darker in the mid-dorsal region, and dotted all over with black spots. The eyes are small, but slightly larger in proportion to the head than in *S. convexa*; they are reniform in shape, prominent, and placed near together.

The first three free thoracic somites are sub-equal; the fourth and fifth are narrow and together equal to the third. The coxal plates of the first three free somites are separated from them by distinct sutures; those of the fifth free somite are broader than the corresponding ones in *S. convexa* and extend backwards as far as the middle of the terminal segment. The pleural plates of the second and third abdominal segments do not extend backwards as far as the extremities of the coxal plates of the seventh thoracic somite; those of the second are slightly longer than those of the third segment.

The terminal segment is considerably broader and more rounded than that of *S. convexa*, and is furnished with a central and two lateral dorsal carinae. The latter are curved and follow the outline of the segment as far as the bases of the uropoda, where they each terminate in a very small spiniform process; these carinae are very much more prominent in *S. convexa*. The middle part of the median carina is obsolete in both species.

REMARKS. The head appendages are of the usual type. Most of the joints of the flagellum of the antennule bear two sensory hairs, one situated near the distal extremity of the joint, the other near its posterior end; Beddard noted a similar arrangement in *S. convexa*. The two outer lobes of the maxilla, like those of *S. convexa*, are broad and bear a number of serrated spines (seventeen on the outer and nine on the inner lobe) instead of the more usual number of two. The basipodite of the maxilliped is separated by a suture from the lamella; the distal joint of the palp is very small.

The second thoracic appendage of the male is figured and described by Audouin and Milne-Edwards, and the types of sensory hairs present on the propodus are very similar to those of the males of *S. convexa* and *S. laevis*; as in these two species, I have observed that there is here also a sexual difference in the form of the spines on the propodus, for in the female the longer type of spine is replaced by one which has its distal end produced into two processes, one of which is slightly longer than the other. Between these processes the central axis is continued as a prolongation extending to about the level of the shorter process (cf. Fig. 12 *b*). A group of plumose setae is present on the carpus of the second thoracic appendage of the male, as in *S. convexa* and *S. laevis*; long plumose setae also fringe the inner margin of the ischium, merus, carpus and propodus of the last thoracic appendage of the male.

The protopodite of each of the first three pairs of pleopods is triangular in shape, and the projecting angle is furnished with three plumose setae in the first of these appendages and two in the second and third. The suture of the exopod of the fourth pleopod is nearly transverse, and the endopod has a rounded distal extremity. The uropoda extend to near the tip of the terminal segment; the exopod is about two-thirds the length of the endopodite, and has a broadly rounded distal extremity bearing a number of long plumose setae. The distal extremity of the endopod is more pointed and is also fringed with plumose setae.

DISTRIBUTION. Shores of South America; the original specimen was found near Valparaiso.

16. **Serolis laevis**, Richardson (Plate XIV, fig. 5).

Serolis laevis, Richardson, 1911, pp. 399, 400, text-fig. 2; Nordenstam, 1933, p. 81.

Through the kindness of Prof. Ch. Gravier I have been able to examine the type specimen of this species from the Museum d'Histoire Naturelle, Paris, and since Richardson's account consists merely of a brief comparison with the allied species *S. plana*, Dana, *S. convexa*, Cunningham, and *S. gaudichaudii*, Aud. et Edw., I include a description. This, however, is necessarily incomplete, as my observations were restricted to such details as could be seen without the removal of any appendages.

DESCRIPTION. The type specimen (Plate XIV, fig. 5) is an adult male measuring 16 mm. in length and 11·5 mm. in greatest width. The body is ovate in shape, white in colour, with a smooth surface, and a slight median dorsal keel. The head is broader than long, broadest anteriorly, with a well-developed rostrum, and with antero-lateral angles narrow. A slight transverse ridge extends across the head just behind the rostrum; the area between the eyes is convex. The eyes are slightly raised, reniform in shape, not deeply pigmented, and larger in proportion to the size of the head than in either *S. convexa* or *S. gaudichaudii.* The lateral portions of the cephalosome are broad, the posterior margin of the segment measuring 11 mm.

The coxal plates of the first three free thoracic somites (3rd–5th) are separated by distinct sutures; the plates of the seventh somite extend backwards to about the middle of the terminal segment, but not as far as the bases of the uropoda: they are longer than the corresponding plates in *S. convexa.* In the male the sternum of each of the third to the seventh thoracic somites bears a small patch of plumose hairs exactly similar to that described for *S. convexa.*

In each of the abdominal segments the posterior margin is slightly produced backwards to form a median dorsal process; this is largest on the third segment. The pleural plates of the second and third abdominal segments are short, not extending beyond the anterior margin of the terminal segment; those of the second segment are slightly the longer. The terminal segment is ovate in shape, with a very small longitudinal median dorsal keel which disappears posteriorly: the extremity of the segment is rounded and not truncate as shown in Richardson's figure and in this specimen the transverse ridge shown in her figure is absent.

The antennule is about half the length of the antenna, the latter extending to about the middle of the third free thoracic somite. The flagellum of the antennule consists of twenty-two joints; the penultimate joint is very short—only about half the length of the terminal one although twice its width: the latter bears four long setae at its distal extremity. The flagellum of the antenna consists of twenty-one joints, of which the two most distal are short (cf. *S. convexa*); the terminal joint bears a group of five setae at its distal extremity.

The form of the maxillula, maxilla and mandible could not be made out in this specimen. The basipodite of the maxilliped is separated by a suture from the lamella, and the terminal joint of the palp is small, as it is also in *S. convexa* and *S. gaudichaudii.* It is probable that in this species, as in *S. convexa* and *S. gaudichaudii,* there is a sexual difference in the form of the spines on the propodus of the second thoracic appendage, for in the male the two types of modified spines are almost exactly similar, though smaller, to those found on the propodus of the males of the above species (see Fig. 14*c*). As in the allied species, a tuft of plumose setae occurs on the carpus.

The third thoracic appendage of the male is more delicate than the second, and the propodus bears on its inner margin two rows of spines, six in each row. Each spine has a truncate extremity on which are situated a number of short hairs. The last thoracic appendage has the posterior margin of the propodus, carpus, merus and anterior half of the ischium fringed with long plumose setae: the remaining appendages are furnished with setae which are either simple or serrated.

The protopodite of each of the first three pairs of pleopods is triangular in shape, the produced angle bearing three plumose setae in the first of these appendages and two in the others. The suture of the fourth pleopod is almost transverse, and the endopod has a rounded extremity. The uropoda extend to near the tip of the terminal segment; the exopod is about two-thirds the length of the endopod, and both are rather narrow and fringed with plumose setae.

Distribution. South Sandwich Islands.

Since the three species *S. convexa*, Cunningham, *S. gaudichaudii*, Aud. et Edw. and *S. laevis*, Richardson, resemble one another rather closely, a short comparison of the three may prove to be of value.

(1) The shape of the body differs in the three species; that of *S. convexa* is pear-shaped, owing largely to the greater length of the terminal segment, and to the fact that the sixth and seventh thoracic somites, with their coxal plates, are distinctly narrower than the preceding ones. This decrease in width is also characteristic of *S. laevis*; but in this species, which is not as large as the other two, the terminal segment is ovate. In *S. gaudichaudii* the terminal segment is oval, with the sixth and seventh thoracic somites *not* distinctly narrower than the preceding ones.

(2) Small median dorsal spines are present on the fourth and fifth thoracic somites and on the first, second and third abdominal segments of *S. convexa*, whereas in the other two species they are only present on the abdominal segments.

(3) The terminal segment of *S. convexa* is roughly five-sided, with three well-developed dorsal carinae: a median one, interrupted in the middle, and two lateral ones, one on either side of the segment, each terminating in a sharp spine. The terminal segment of *S. gaudichaudii* is rounded, nearly as broad as long; it bears three dorsal carinae, a median one interrupted in the middle, and two lateral ones, which are curved and follow the outline of the segment as far as the bases of the uropoda where each terminates in a very small spiniform process: these carinae are less pronounced in this species. In *S. laevis* the median and lateral carinae of the terminal segment are almost obsolete.

(4) The colour of the three species differs: that of *S. convexa* is a uniform pale brown, that of *S. gaudichaudii* is brown, darker towards the middle line and dotted all over with black spots, whilst that of *S. laevis* is white.

(5) The three species resemble one another and differ from the majority of species in possessing maxillae in which the two articulating lobes are broad; and each lobe bears eight or nine pectinate setae instead of the more usual number of two. The distal joint of the palp of the maxilliped is also smaller than usual.

(6) The two species *S. convexa* and *S. gaudichaudii*, and probably also *S. laevis*, are characterized by a sexual difference not found in any other species; the form of the modified setae which occur on the propodus of the second thoracic appendage differs in the two sexes (see descriptions of species).

(7) Long plumose setae are present on the carpus of the second thoracic appendage, and on the posterior margins of the propodus, carpus, merus and ischium of the last thoracic appendage of the adult male in all three species.

(8) A further sexual character of the adult male of *S. convexa* and *S. laevis* is the presence of a patch of plumose setae on the sternum of each of the third to the seventh thoracic somites. I have not been able to examine adult male specimens of *S. gaudichaudii*, and I am unable to say whether or not it also possesses this character.

(9) The distribution of *S. convexa* and *S. gaudichaudii* is somewhat similar. The former occurs off the coast of the Argentine Republic and around the Falkland Islands; the latter has been recorded from the shores of South America and off Valparaiso. The only record of *S. laevis* is the South Sandwich Islands, a locality farther east than any of those recorded for the two former species.

Nordenstam, 1933, includes *S. laevis* as a synonym of *S. convexa*.

17. **Serolis gerlachei, Monod.**

S. gerlachei, Monod, 1925, p. 299; 1926, pp. 36, 37, text-figs. 35–7.

Only one specimen of this species, an immature male, has so far been recorded, and I wish to express my gratitude to Dr von Straelen of the Musée Royal d'Histoire Naturelle de Belgique for allowing me to examine it.

DIAGNOSTIC CHARACTERS. The body is longer than broad, strongly arched and with a median longitudinal keel; it measures 10 mm. in length and 8 mm. in greatest breadth. The breadth of the head is about equal to its length, excluding the end of the median spine. The head is broadest anteriorly; the antero-lateral angles are produced beyond the anterior margin, which is excavated on either side of a minute median rostrum for the reception of the antennules. The antero-lateral angles are marked off by a transverse ridge which extends across the head immediately behind the base of the rostrum; the area behind this ridge and between the anterior ends of the eyes is raised, and is separated by a slight groove from the raised area between the eyes. The latter area is divided into two lateral oval prominences and a median area which is produced backwards as a long acute spine extending to about the middle of the second free somite. The eyes are reniform and pigmented.

The first three free somites (3rd–5th) are sub-equal in length. The third has its posterior margin produced into a small median spine; the fourth and fifth free somites are together equal in length to the first free somite, and are without spines. The coxal plates of all the thoracic somites are compact and those of the first three free somites are separated from them by sutures. The coxal plates of the seventh thoracic somite extend for a short distance beyond the bases of the uropoda and farther than the pleural plates of the second and third abdominal segments, the latter of which are a little longer than the former and reach to the bases of the uropoda. The terga of the three abdominal segments are each produced posteriorly into a small median dorsal spine.

The terminal segment is roughly pentagonal in outline, slightly longer than broad, with a sub-acute posterior extremity. On its dorsal surface, in an anterior median position, is a small raised triangular area with its apex directed backwards; this is continuous with a median carina which extends to the posterior extremity of the segment. On either side, arising from the angle of the base of the triangle, is another carina which runs obliquely outwards and terminates in a spine some distance within the lateral margin, just behind the level of the base of the uropod. Midway between this and the median carina, and running parallel with the latter, is a third carina which starts anteriorly a little behind the apex of the triangular area and terminates posteriorly a short distance within the margin of the segment. Just within the anterior and lateral margins of the segment is a narrow ridge which follows the outline of the segment as far as the base of the uropod.

REMARKS. Monod (1926, p. 37) does not describe any of the appendages of this species. He figures most of them; but some of the figures are inaccurate in so far as they do not show the complete structure of the appendage concerned.

The flagellum of the antenna consists of fifteen joints; on the third to the ninth joints, just within the anterior margin, is a row of small spines, which have been omitted in Monod's fig. 36 A. Only the distal portion of the outer lobe of the maxillula (fig. 37 D) is figured, although both lobes can be seen in Monod's preparation; the inner lobe is broken near its base and is lying partly covered over by the outer lobe. The appendage is of the usual type; the inner lobe is about half the length of the outer, with a slightly broadened distal extremity bearing one short seta. The figure of the maxilla (fig. 37 E) is also incomplete, as it does not show the sutures or the basal segments of the appendage. The basipodite of the maxilliped (fig. 37 F) is separated from its lamella by a suture.

In this species a small extra joint bearing a number of setae is found at the outer distal angle of the third joint of the palp: a similar joint has already been described in *S. schythei*, Lütken, and *S. polaris*, Richardson. The suture of the exopod of the fourth pleopod is transverse, and its outer distal border is fringed with long plumose setae; the endopod is rounded. The uropod is figured by Monod (fig. 37 G), but the scattered plumose setae on the margins of both endopod and exopod are not shown.

LOCALITY. 71° 19′ S, 87° 37′ W, at a depth of 400 m.

18. **Serolis meridionalis**, Hodgson.

S. meridionalis, Vanhöffen, 1914, p. 518, fig. 51.

In the Report of the Scientific Results of the Voyage of S.Y. 'Scotia' (vol. IV (1), pl. xi) there is a photograph of this species taken by W. S. Bruce. The species was named by Hodgson and it has since been recorded and briefly described by Vanhöffen (1914, p. 518) from material collected during the Deutsche Südpolar-Expedition. Through the kindness of the Keeper of the Royal Scottish Museum I have been able to examine the type specimen.

DIAGNOSTIC CHARACTERS. The type is an adult female in the breeding phase. It is not possible to give its exact size, as unfortunately the greater portion of the much-produced terminal process is broken off; nevertheless it reaches a length of 80 mm. and a breadth of 55 mm., and it is probable that the complete length would be from 10 to 15 mm. greater. The specimen is considerably larger than that of Vanhöffen; this is also a female in the breeding phase, and it is 59 mm. in length and 35 mm. in greatest breadth. The species is by far the largest in the genus.

The head is broader than long, with its lateral margins parallel and with its anterior margin excavated for the reception of the antennules. In its antero-lateral angle, on either side, is a somewhat triangular-shaped prominence, whilst behind this is a second one, oval in shape, extending obliquely inwards from the postero-lateral angle. On the outer side of this prominence is the long narrow eye, which is devoid of pigment. Vanhöffen (p. 518) does not mention the eyes in his description; but he illustrates them (fig. 51 *a*), using cross-hatching which, however, may be intended to represent optical units and not pigment.

Either the absence or the reduction in the amount of pigment, or the absence or the reduction in the size of the eyes, seems to be a characteristic of the deep-sea forms, for the colour of the eyes of *S. bromleyana*, Suhm, is whitish yellow, and that of *S. neaera*, Beddard, is bluish black owing to the comparatively small amount of pigment, whilst in *S. gracilis*, Beddard, the eyes are small and inconspicuous and in *S. antarctica*, Beddard, they are absent.

On the inner side of each eye prominence is a small backwardly projecting spine; the rest of the area between the eyes is raised and divided posteriorly into a median and two lateral parts, the latter of which have their posterior margins toothed; the posterior margin of the median part is straight. The lateral portion of the cephalosome, on either side, is divided by a transverse groove which extends from the posterior angle of the eye to the lateral margin.

The coxal plates are curved and sickle-shaped; the articular processes which unite together the succeeding plates are placed at some distance from the junction between the terga and the plates; those of the first three free somites are separated from them by sutures. The coxal plates of the seventh thoracic somite extend backwards to about the base of the spine of the terminal segment. The pleural plates of the second and third abdominal segments are of approximately equal length and do not reach quite as far as the base of the uropoda.

The terminal segment is considerably longer than broad; it is broadest at the level of the bases of the uropoda, from which point it gradually narrows to form a long spiniform process, the lateral margins of which are deeply serrated. A longitudinal median toothed keel runs from near the anterior margin to the end of the terminal process, and between the anterior end of the keel and the anterior margin are two small, backwardly directed, rounded spines, situated one on either side of the median line. Between these spines and the median keel, on either side, is an oblique transverse ridge which extends to the base of the uropod and terminates in a small spine. The uropoda are comparatively small. Unfortunately in the type specimen one is missing and the other incomplete; the protopodite is only slightly produced on its inner side.

Remarks. Vanhöffen gives no description of the mouth-parts and appendages of this species. I append a few notes, which are necessarily brief as my observations have had to be restricted to those made on the entire specimen.

The antennule is not much shorter than the antenna. The first joint of the peduncle is almost triangular in shape; the second is 7 mm. long; the third is shorter than the second, measuring 5·5 mm., and the fourth is 3·5 mm. in length. Dorsal grooves are present on the second and third joints. The flagellum measures 18 mm. in length and consists of thirty-three joints.

The antenna consists of a peduncle of five joints, the first two of which are short;

the third measures 7 mm., the fourth 11 mm., and the fifth 14 mm. in length. There is a deep longitudinal groove on the dorsal surface of each of the last three peduncular joints. The flagellum is considerably shorter than that of the antennule; it measures 11 mm. in length and consists of only seventeen joints.

The basipodite of the maxilliped is separated from the lamella by a suture; the suture between the coxopodite and the epipodite is not so easy to trace, but it appears to be present. As in the other deep-sea forms a small tubercle, covered with hairs, is present near the base of the second joint of the palp.

The propodus of the second thoracic appendage is broad, and its inner margin is armed with a row of thirty-four somewhat triangular processes alternating with a row of modified spines, the detailed structure of which it was not possible to make out. The inner distal extremity of the carpus is crenulate and bears two short spines. The remaining thoracic appendages are slender; as in *S. bromleyana*, Suhm, the fourth joint is longer than either the third or the fifth. The setae, which are restricted to the distal ends of the propodus, carpus and merus, and to two groups on the outer margins of the merus and the carpus, are all of the simple variety.

The sterna of the abdominal segments are produced backwards in the median line and the resulting spines increase in size from before backwards. The protopodite of each of the first three pairs of pleopods is large, and roughly triangular in shape; I have been unable to see any spines on the produced angles. The suture of the exopod of both the fourth and fifth pleopods is oblique, and in both cases the endopod is entire.

DISTRIBUTION. Off Coats Land, in 2759 m.

A considerable amount of confusion surrounds the identification of the two following species, *S. trilobitoides*, Eights (Pl. XIV, fig. 7) and *S. cornuta*, Studer (Pl. XIV, fig. 6). The former species was described by Eights in 1833 and the latter by Studer in 1879, although he mentioned it in an earlier paper (1876) under the name of *Brongniarta cornuta*. Neither the descriptions nor the figures are detailed or accurate, and since the two species are very much alike and have never both been recorded, until now, in any single collection, and since Studer (1879) does not bring out the main points of difference between the two, it is easy to see how such confusion has arisen.

Beddard (1884*b*), in his account of the Challenger Serolids, describes and figures certain specimens (pp. 49–53) which he assigns to *S. cornuta*. I have examined these specimens at the British Museum and compared them with those of the present collection and I have come to the conclusion that his specimens are *S. trilobitoides* and not *S. cornuta*, and that actually *S. cornuta* is not represented in the Museum collection.

Hodgson (1910), who redescribed *S. trilobitoides*, considers that the two species are identical, for he says, "I have, I think, satisfactorily proved that *S. cornutus*, Studer, is merely the immature form of *S. trilobitoides*, Eights", and he includes *S. cornuta* as a synonym of *S. trilobitoides*. In so far as Hodgson's results are drawn from existing literature and since Beddard's figures prove to be those of *S. trilobitoides* and not

S. cornuta, his conclusions are justified; but I may point out that even the smallest specimens of *S. cornuta* exhibit the characteristic shape of the adult. It is interesting to note that Studer does not state the sex of the specimen he figures; nevertheless, Beddard says it is a male, whilst Hodgson, referring to the same figure, says, "this figure, from its great breadth is probably a female". By this statement Hodgson recognizes one of the chief differences between the two species, but, as is usual amongst the Serolids, the male has the greater proportional width. The only other record of either species is that given by Monod (1926) for *S. trilobitoides*, Eights.

The most noticeable point of difference between the two species lies in the relative proportions of the various parts of the body. In both species, the male is broader in proportion to its length than is the female. The following comparison is drawn between two adult males.

(1) The shape of the body of *S. cornuta*, excluding the terminal spine of the last segment, is almost circular, whilst that of *S. trilobitoides* is broadly ovate; the actual measurements are:

S. cornuta: length minus terminal spine = 49 mm.;
breadth = 49 mm.;
terminal spine = 4 mm.
S. trilobitoides: length minus terminal spine = 52 mm.;
breadth = 48 mm.;
terminal spine = 2 mm.

The proportions of the body in the specimens in the British Museum and also of Hodgson's specimen agree with those of *S. trilobitoides*, whilst the measurements given by Eights (70 × 57 mm.) for that species seem to point to the same general shape, though the ratio of length to breadth is slightly greater, 1·22 : 1 as compared with 1·12 : 1. Studer (1879) gives the length of his largest specimen of *S. cornuta* as 30 mm. and makes no mention of its breadth; but if the specimen is figured correctly his specimen agrees in shape with those of the present collection, for the length without the terminal spine is 32 mm., the breadth also 32 mm., and the length of the spine 3·5 mm.

(2) The terminal segments of both species (Fig. 13 *a*, *b*) are pentagonal in outline; but that of *S. cornuta* is longer than broad with a much more acute posterior extremity and with a longer terminal spine, whilst that of *S. trilobitoides* is broader than long; the measurements taken from two adult male specimens are:

S. cornuta: length of segment + spine = 19 mm.;
length of spine = 4 mm.;
breadth = 17 mm.
S. trilobitoides: length of segment + spine = 18 mm.;
length of spine = 2 mm.;
breadth = 19 mm.

This difference in shape can be clearly seen if the figures of Beddard (1884 *b*, pl. i, figs. 1–3) and of Hodgson (1910, pl. iv, figs. 1, 2) are compared with those of Studer (1879, taf. iii, figs. 1, 3) for *S. cornuta*.

(3) The spines on the median dorsal keel of the terminal segment are much larger and fewer in number in *S. cornuta* than in *S. trilobitoides*.

(4) The length of the coxal plates of the seventh thoracic somite also differs in the two species. In *S. cornuta* (Fig. 13 *b*) they extend backwards almost to the level reached by the tip of the terminal segment, and a considerable distance beyond that reached by the pleural plates of the second and third abdominal segments; the pleural plates of the second segment are slightly longer than those of the third, and both pairs extend backwards beyond the distal end of the protopodite of the uropod. In *S. trilobitoides* (Fig. 13 *a*) the coxal plates reach backwards to a level half-way between the attachment of the uropod and the tip of the terminal segment and a little way beyond the pleural plates of the abdominal segments: the pleural plates of the second abdominal segment are very slightly longer than those of the third.

The British Museum specimens of "*Serolis cornuta*" agree with *S. trilobitoides* on this point, as do also the figures of Hodgson (1910, pl. iv, figs. 1, 2), though those of Beddard (1884 *b*) show the coxal plates of the seventh thoracic somite in the male (pl. i, figs. 1, 3) rather more than their normal length though not as long as those of the male in the true *S. cornuta*. Studer (1879), in his original description of *S. cornuta*, states that the coxal plates of the seventh thoracic somite extend beyond the middle of the caudal shield, and in his figure (taf. iii, fig. 1) shows them extending to the base of the terminal spine, the level reached by the corresponding plates in the females of this collection. In his figure of the abdomen (taf. iii, fig. 3), which also includes these plates, they are shown very much shorter, whilst the pleural plates of the abdominal segments do not reach as far as the level of attachment of the uropods. Since in all existing figures, and in all examined specimens of *both* species, the pleural plates extend backwards beyond the level of the articulation of the uropod, it may be presumed that on these points Studer's figure (fig. 3) is inaccurate, though the actual form of the terminal segment appears to be correct.

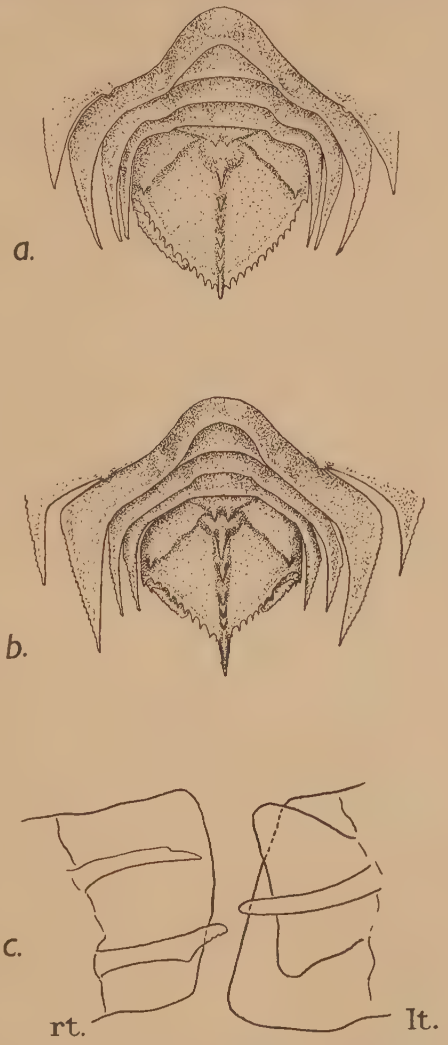

Fig. 13. *Serolis trilobitoides*, Eights, and *S. cornuta*, Studer.
S. trilobitoides, Eights. *a*, abdominal and terminal segments: × 2.
S. cornuta, Studer. *b*, abdominal and terminal segments: × 2. *c*, cutting edges of mandible: × 40.

(5) Observations made on living specimens of the two species show that a further

difference exists between them; the colour of *S. cornuta* is pale grey with dark brown spots of pigment (for distribution see Plate XIV, fig. 6), whilst that of *S. trilobitoides* is pale horn colour, blotched and with a darker colour which varies from maroon to pale terra-cotta. The colour given by Studer for *S. cornuta* is pale with a darker posterior edge to each segment.

(6) With regard to the distribution of the two species, both have been recorded from Kerguelen, *S. cornuta* from the west of the island, and *S. trilobitoides* from Betsy Cove. Studer's material of *S. cornuta* came from this locality and also from the Crozet Islands, whilst that of the present collection comes from the South Orkneys and South Sandwich Islands. The specimens of *S. trilobitoides* in the present collection come from Clarence Island and the South Shetlands, and the species has previously been recorded from the latter locality. Hodgson's material came from a station in 67° 21′ 46″ S, 155° 21′ 10″ E, which is much farther east than any other recorded for either species.

19. **Serolis cornuta**, Studer (Figs. 1 *a*, *c*, 13 *b*, *c*; Plate XIV, fig. 6).

S. cornuta, Studer, 1879, pp. 21–24, pl. iii, figs. 1–7; 1884, p. 7.
Brongniartia cornuta, Studer, 1876, p. 75.

Occurrence. St. 164: South Orkneys, 24–36 m.; 2 ♀♀ (b.), 6 ♀♀ (non-b.), 2 adult ♂♂, 4 immature ♂♂, and a number of small specimens.
St. 363: South Sandwich Islands, 329–278 m.; 2 ♀♀ (non-b.), 1 young ♂.

DIAGNOSTIC CHARACTERS. The body of the adult male (Plate XIV, fig. 6), excluding the spine on the terminal segment, is circular in outline, that of the female is not quite as broad; the largest male in the collection measures 49 mm. in length, excluding the terminal spine of 4 mm., and 49 mm. in breadth, whilst the female is 51·5 mm. long, without the terminal spine, and 49 mm. in greatest breadth. The colour of the living animal is pale grey with dark brown spots of pigment.

The head is shield-shaped, broadest anteriorly, with the anterior margin excavated on either side of the small median rostrum for the reception of the antennules; immediately behind this is a transverse ridge extending to the sides of the head. In front of and between the eyes, is a squarish raised area with its posterior margin slightly concave, the two ends being somewhat produced backwards; the posterior margin is separated from the remaining portion of the head by a deep groove. The area between the eyes is raised, and separated by grooves from the elongated protuberances on the outer sides of which the eyes are situated. The area between the eyes is divided into three parts, of which the central is less convex and has its posterior margin produced into a small, median, somewhat rhombic-shaped area which bears a small rounded pigment spot; each of the lateral parts is convex, oval in shape and produced posteriorly into a small spine.

The eyes are long, reniform in shape, rather narrow, and containing black pigment. The lateral portion of the cephalosome is divided into an anterior and a posterior part by a well-marked transverse groove, which extends outwards to the lateral margin from a point near the postero-lateral angle of the eye.

The thoracic somites are all sub-equal, with well-developed coxal plates, those of the third to the fifth somites being separated by sutures. The coxal plates are sickle-shaped, with the terminal portions from the articular processes outwards, curved first forwards and then outwards, so that a space is left between two consecutive plates. Those of the seventh somite are produced backwards to near the end of the terminal segment in the male, and to about the level of the base of the terminal spine in the female.

The first three abdominal segments are sub-equal (Fig. 13 *b*), each a little more than half the length of the thoracic somites. The pleural plates of the second and third segments are long, narrow and produced backwards beyond the point of attachment of the uropod, those of the second being slightly the longer: the outer margins of the coxal and pleural plates are serrated. In the female the sterna of the first three abdominal segments each have their posterior margin produced into a median spine which is largest on the third segment; these are hardly developed in the male.

The terminal segment (Fig. 13 *b*) is pentagonal in outline, slightly longer than broad, terminating in a long spiniform process which is slightly upturned; on its dorsal surface is a median dorsal keel bearing five large spines directed upwards and slightly backwards, and decreasing in size from before backwards. The area in front of the first spine is raised and bears two small spines, from the base of each of which a transverse oblique carina extends outwards to near the lateral margin where it ends in a sharp backwardly directed spine. The margin between the attachment of the uropod and the terminal spine is sharply serrated.

REMARKS. As the descriptions of the mouth-parts and appendages given by Studer (1879, pp. 21–24) are very brief, some further details are given here. The appendages are all of the normal type and bear a very close resemblance to those of *S. trilobitoides*, Eights. The antennule and the antenna are described by Studer, but he failed to observe that a dorsal groove is present on each of the first three peduncular joints of the former, and of the second to fifth joint of the latter. The surface of each groove, like that of *S. trilobitoides*, is covered by short setae which are all directed towards the centre of the groove in a distal direction. The number of joints in the flagella of both antennule and antenna appears to be greater than that given by Studer; his number for the former is twenty-two and for the latter fourteen, whereas in specimens in the present collection these numbers are increased to thirty and eighteen respectively. A further detail omitted from Studer's description is the mention of the row of teeth occurring on the ventral surface of the middle joints of the flagellum of the antenna: these are also seen in a corresponding position in *S. trilobitoides* and were figured by Beddard (1884 *b*, pl. i, fig. 6).

The cutting edges of the mandibles are strongly chitinous: their form is shown in Fig. 13 *c*. The outer lobe of the maxillula (Fig. 1 *a*) bears nine strong spines and an inner pectinate seta on its distal extremity. The inner lobe is broad distally, with a series of extremely small toothed spines on the outer margin of its rounded end, and a single longer spine near its inner margin. There are two setae, on both the inner and outer lobes of the left maxilla (Fig. 1 *c*), whilst on the right there are two on the outer and three on the inner lobe: the fixed lobe of both bears about thirty setae.

The basipodite of the maxilliped is separated from its lamella by a suture. The second joint of the palp is broad, with its margin fringed with setae, some of which have their distal ends flattened and toothed; the third joint is almost parallel-sided with its truncate distal extremity fringed with setae. The ventral surface of the palp and of the basipodite is sparsely covered with delicate setae. The modified spines on the inner margin of the propodus of the second thoracic appendage are similar to those on the corresponding joint of *S. trilobitoides*, and are very like those figured for *S. platygaster*, n.sp. (Fig. 19 *b*). The propodus of the third thoracic appendage of the adult male bears a double row of seven modified spines at the proximal end of its inner margin and a further five extend in a median position towards the distal end of joint. These spines are short and stout, with a delicate distal extremity and with the distal half, facing towards the distal end of the propodus, covered with short dense hairs. Similar setae are found on the inner margin of the carpus, and a single one at the inner distal angle of the merus. The remaining appendages bear setae which are either simple or pectinate; the latter, which are more abundant on the joints of the last appendage, are found towards their distal ends. The last pair of thoracic appendages is much smaller than the rest: in that of the mature male the propodus is broader than the corresponding joint in the female, and its outer margin is armed with a number of strong spines; the dactylus in the male is also slightly recurved.

The protopodite of the first three pairs of pleopods has a produced angle which bears long plumose setae, three on that of the first and two on each of the second and third. The sutures of the exopod of both fourth and fifth pleopods are oblique and placed rather near their distal ends: the endopods of both are large and undivided. The protopodite of the uropod has its inner angle produced into a sharp spine. The endopod is a little longer than the exopod; both are elongate-oval in shape with pointed distal extremities. The apices of both exopod and endopod and the outer margin of the former are deeply serrated.

DISTRIBUTION. Studer's specimens were collected from the Crozet Islands and a locality west of Kerguelen Island; those in the present collection come from the South Orkneys and South Sandwich Islands.

20. **Serolis trilobitoides**, Eights (Fig. 13 *a*; Plate XIV, fig. 7).

S. trilobitoides, Eights, 1833, pp. 53–7, 2 plates.
S. cornuta, Beddard, 1884 *b*, pp. 49–53, pl. i, figs. 1–6.
S. trilobitoides, Eights, Hodgson, 1910, pp. 23–30, pl. iv, figs. 1–8; Monod, 1926, p. 38; Nordenstam, 1933, pp. 59–60, text-fig. 5 *a*.
S. zoiphila, Stechow, 1921, pp. 221–3; Nierstrasz, 1931, pp. 222–4.

Occurrence. St. 170: Clarence Island, 324 m.; 1 ♀ (non-b.), 1 immature specimen.
St. 172: South Shetlands, 525 m.; 1 ♂ and 3 immature specimens.

DIAGNOSTIC CHARACTERS. Body (Plate XIV, fig. 7) broadly ovate. The largest male in the collection is 52 mm. in length without the terminal spine of 2 mm., and 48 mm. in greatest breadth; the female is 51·5 mm. in length (including the terminal spine) and

44 mm. in breadth. The colour of living specimens was pale horn, blotched and mottled with a darker colour which varied from maroon to pale terra-cotta.

The head is shield-shaped and almost identical with that of *S. cornuta*, Studer: it is broadest anteriorly, with the anterior margin excavated on either side of the small median rostrum for the reception of the antennules; immediately behind this is a transverse ridge extending laterally to the sides of the head. In front of and between the eyes is a square raised area with its posterior margin slightly concave, the two angles being somewhat produced backwards. The area between the eyes, which, except anteriorly, is separated from them by deep grooves, is convex and is divided posteriorly into a median and two lateral areas, each of the latter being in the form of a flattened, somewhat oval enlargement, produced backwards into a very small spine. The median area is produced into a narrow four-sided plate with a small dark tubercle in its centre; this lies between and rather behind the two lateral enlargements. The eyes are reniform in shape, rather narrow, and containing black pigment.

The lateral portion of the cephalosome is divided on either side into an anterior and a posterior portion by a well-marked transverse groove, which extends outwards from a point near the postero-lateral margin of the eye to the lateral margin. A further ridge on the anterior portion arises near the end of the anterior transverse ridge of the head.

The thoracic somites increase in length from the third (first free) to the fifth; the fifth, sixth, and seventh are sub-equal. Each somite has well-developed coxal plates, those of the third, fourth and fifth being separated by sutures. The plates are somewhat sickle-shaped, with the terminal portion from the articular process outwards curved backwards, and outwards, following closely the outline of the preceding one (cf. *S. cornuta*, Studer). The coxal plates of the seventh thoracic somite are produced backwards to a point half-way between the attachment of the uropod and the end of the terminal segment, reaching slightly beyond the pleural plates of the abdominal segments; the lengths of these plates are almost the same in both sexes.

The first three abdominal segments are sub-equal (Fig. 13 *a*), with the sterna each bearing a median spine, increasing in size from before backwards; these are well developed in the female, but only slightly in the male. The pleural plates of the second and third abdominal segments extend backwards almost as far as the coxal plates of the seventh thoracic somite; those of the second segment are slightly the longer. The outer margins of the coxal and pleural plates are minutely though not so deeply serrated as those of *S. cornuta*.

The terminal segment (Fig. 13 *a*) is pentagonal in outline, ending posteriorly in a spiniform process which is not as long or acute as the corresponding one in *S. cornuta*. The segment is broader than long, that of the largest specimen measuring 18 mm. in length (including the terminal spiniform process of 2 mm.) and 19 mm. in greatest width. On the dorsal surface is a longitudinal median keel bearing five or six recurved teeth; the first of these is the largest, but none are as large as those in a similar position in *S. cornuta*. The area in front of the first tooth is raised and bears two small spines, and from the base of each an oblique ridge extends to near the lateral margin at the level of the attachment of the uropod, where it ends in a small, backwardly directed spine. The margins of the segment behind the base of the uropoda are serrated.

REMARKS. The appendages are of the usual type, and have been described by Beddard (1884*b*, pp. 51–3, pl. i, figs. 1–16, as *S. cornuta*), and by Hodgson (1910, p. 26, pl. iv).

The first three joints of the peduncle of the antennule and the second to fifth of the antenna, are marked by ridges which extend along the dorsal surface of the joints not far from their posterior margins, and the surface of the groove towards the anterior side of each ridge is covered with short setae, all of which are directed towards the centre of the groove and in a distal direction. This point has not been described previously. The number of joints in the antennular and antennal flagella appears to be greater in the present specimens than previously noted; the antennule has forty-one joints as compared with twenty-five in earlier descriptions, and the antenna twenty as compared with sixteen. The row of teeth occurring on the middle joints of the antennal flagellum, figured by Beddard (1884*b*, pl. i, fig. 6), occurs on the ventral surfaces of the joints.

Hodgson (1910, p. 28) states that he is unable to detect any division in the basal plate of the maxilliped even with a $\frac{1}{6}$ objective; my observations agree with those of Beddard (1884*b*, pl. i, fig. 11), who shows a suture between the coxal plate and the epipod. Hodgson's figure (pl. iv, fig. 6) is thus inaccurate on this point.

The forms of the modified spines which arm the inner margin of the propodus of the second thoracic appendage are figured by Hodgson (1910, pl. iv, figs. 7, 8). The propodus of the third thoracic appendage of the adult male is modified in the usual way; the inner margin of the enlarged propodus bears spines of the type usual to that joint—seven pairs are arranged around the proximal portion of margin, and a further five spines form a median row towards its distal end.

Both Beddard (1884*b*, p. 52) and Hodgson (1910, p. 30) state that the exopod of the uropod is almost twice as long as the endopod. This, however, is not correct: the endopod is the longer, but only slightly so, the actual measurements in a large specimen being: endopod 8 mm., exopod 7 mm. Hodgson's statement (p. 30) that the exopod is two-jointed, "the terminal one being scarcely half as long as the other", is also incorrect: in this species, as in all other Serolids, the exopod consists of a single joint.

DISTRIBUTION. This species has been recorded from Betsy Cove, Kerguelen, and from Clarence Island and the South Shetlands, as well as from a locality much farther east: 67° 21′ 46″ S, 155° 21′ 10″ E (Hodgson).

[**Serolis zoiphila**, Stechow.

S. zoiphila, Stechow, 1921, pp. 221–3; Nierstrasz, 1931, pp. 222–4.

Stechow (1921, pp. 221–3) describes a new species of *Obelia* (*O. longa*) which he found attached to the caudal segment of a species of *Serolis*. The only statement he makes concerning this species is that it occurred at Kerguelen and that he wishes to call it *Serolis zoiphila*, n.sp. A photograph is given which clearly shows it to be a specimen of *S. trilobitoides*, Eights, and I have included the name in the synonymy of that species. The name is included in the list of Serolids given by Nierstrasz (1931).]

21. **Serolis antarctica**, Beddard.

S. antarctica, Beddard, 1884 *a*, p. 333; 1884 *b*, pp. 63–6, pl. iii, figs. 1–6.

Diagnostic characters. This species, which lives in deep water, has not been recorded since it was originally described by Beddard. The largest male measures 33 mm. in length and 31 mm. in greatest breadth, and the largest female 31 mm. in length and 26 mm. in breadth, so that the male is broader in proportion to its length than the female.

The eyes are absent, their place being taken by rounded tubercles covered with chitinous integument in which there is no trace of any optical structures; between these tubercles is a median one which is short and blunt.

The dorsal surface of the body is strongly sculptured and the posterior margin of each of the thoracic and the abdominal segments is produced backwards as a short, blunt, median spine. The coxal plates are comparatively short and flat; those of the first three free thoracic somites are almost rectangular in shape and are separated from their respective somites by sutures. The coxal plates of the seventh somite of the male are produced backwards to a short distance beyond the end of the terminal segment; those of the female do not extend beyond the terminal segment. The pleural plates of the second and third abdominal segments reach to the base of the uropoda, those of the latter being slightly the longer.

The terminal segment is more or less hexagonal in shape; the lateral edges are turned downwards so that the uropoda cannot be seen from the dorsal surface; "there is a median longitudinal keel which bifurcates at about the end of the anterior fifth, on either side is a Y-shaped keel inclined at an oblique angle; the portion of the caudal shield which lies between the median and lateral keels is flat, the part which lies outside the inner fork of the lateral keel is bent downwards; the posterior end of the caudal shield is slightly bent up" (Beddard, 1884 *b*, p. 65).

Occurrence. Off Pernambuco (1375–1600 fathoms), and between Prince Edward Island and the Crozets.

22. **Serolis bromleyana**, Suhm.

S. bromleyana, Suhm, 1874, p. xix; 1876, p. 591; Beddard, 1884 *b*, pp. 53–7, pl. iv.

Diagnostic characters. This species can no longer be considered the largest of the genus, for the length of the largest known male is only 54 mm., which is less than two-thirds the length of Hodgson's female of *S. meridionalis*. The breadths of the specimens are approximately the same, that of the former being 56 mm., that of the latter 55 mm.; the length of the female is 45 mm., and its greatest breadth 39 mm.

The body is more or less oval in shape, and its surface is covered with shallow pits and scattered hairs: the colour (in alcohol) is "violet-grey with whitish yellow patches upon the caudal shield and posterior portion of the thorax" (Beddard, 1884 *b*, p. 53).

The head is longer than broad, owing to the projection of its antero-lateral portions for some distance beyond the rostrum: these antero-lateral portions are separated from the rest of the head by a transverse ridge which runs from just behind the rostrum to the lateral margin on either side. This character distinguishes the species from all other deep-sea forms. The central portion of the head between the eyes is strongly convex and is divided into three areas—"two round convexities which lie to the inner side of and behind each eye, and a median T-shaped elevation, at the upper end of which, on a level with the anterior portion of the eyes, are four tubercles arranged in a semicircle with the concavity directed forwards; at the hinder extremity is another short tubercle" (Beddard, 1884 *b*, p. 54). The eyes are whitish yellow in colour.

The posterior border of each of the third to seventh thoracic somites is produced into a minute median dorsal spiniform process; the third, fourth and fifth somites are separated by sutures from their coxal plates. The coxal plates are long and sickle-shaped and increase in length from before backwards; those of the seventh thoracic somite extend for a considerable distance behind the termination of the terminal segment and are longer in the male than in the female. In the male the pleural plates of the second abdominal segments extend beyond, whilst those of the third extend as far as the tip of the terminal segment; in the female those of the third segment hardly reach as far as the extremity of the terminal segment. The terminal segment is broader than long, somewhat pentagonal in outline, with the posterior extremity notched and slightly turned up; on its dorsal surface is a median longitudinal keel, and also, on either side, a short flat spine, placed near the lateral margin on a level with the attachment of the uropod.

REMARKS. There are two points in which my observations on this species differ from those of Beddard. In the first place, he states in his description of the maxilliped, that "the stipes and lamina are not separated by a complete suture", or, in other words, that the basipodite and lamella are not completely separated. In his figure (pl. iv, fig. 8), however, he shows these two lobes as separated by a suture, but the coxal joint fused with the epipodite. Actually the basipodite is separated by a suture from the lamella and the coxa by a suture from the epipod. The second point is that Beddard describes the third thoracic appendage of the male (p. 56) but calls it the second appendage, whilst actually he omits any description of the second. The second appendage is of the usual type and bears on its propodus alternating rows of two varieties of modified spines very similar in appearance to those found in *S. beddardi*, Calman (Fig. 3 *b*).

OCCURRENCE. Off the east coast of New Zealand, in 1100 and 700 fathoms, and close to the Antarctic Ice-Barrier in 1975 fathoms.

23. **Serolis neaera**, Beddard.

S. neaera, Beddard, 1884 *a*, pt. iii, p. 331; Beddard, 1884 *b*, p. 57, pl. v, figs. 1–11.

Occurrence. St. WS 212: 49° 22′ S, 60° 10′ W, 242–249 m.; 8 immature.
St. WS 213: 49° 22′ S, 60° 10′ W, 249–239 m.; 1 ♀ (b.), 1 immature.
St. WS 236: 46° 55′ S, 60° 40′ W, 272–300 m.; 2 ♀♀ (b.), 2 ♂♂, 1 immature.
St. WS 244: 52° 00′ S, 62° 40′ W, 253–247 m.; 2 ♂♂, 2 ♀♀ (b.), 6 immature.
St. WS 773: 47° 28′ S, 60° 51′ W, 291–296 m.; 1 ♀ (b.), 3 immature.

St. WS 820: 52° 53′ 15″ S, 61° 51′ W, 351–367 m.
St. WS 821: 52° 55′ 45″ S, 60° 55′ W, 461–468 m.; 1 ♂, several damaged specimens.
St. WS 839: 53° 30′ 15″ S, 63° 29′ W, 403–434 m.; 1 ♀ (non-b.), 5 immature specimens.

Diagnostic characters. The specimens in the collection are smaller than those taken by the 'Challenger'. The actual body length of both the largest male and female is 26 mm.; but if the length of the seventh coxal plates is included this is increased to 37·5 mm. in the former, and 33 mm. in the latter, the difference in length being due to the greater length of the coxal plates of the male. As in most species the male is proportionately broader than the female and measures 33 mm. as compared with 28 mm., the width of the female.

The head is broader than long, broadest anteriorly, with a small rostrum behind which a transverse ridge extends laterally to the margin of the cephalosome; immediately behind this is a fairly deep groove. The area between the eyes is convex, and extending across this area, not far behind the anterior margins of the eyes, is a transverse row of four spines, the inner ones of which are the smaller. The posterior margin of the head is indented and forms three projections, the lateral of which are somewhat triangular in shape; the central one is elongated transversely and is oval in shape. Unlike other deep-sea forms the eyes are large, being both long and broad; they are reniform in shape but not deeply pigmented, the colour being bluish-black. According to Beddard (1884 *b*, p. 26) the minute structure resembles that of the eyes of *S. bromleyana*, Suhm, but is a little less degenerate.

On the lateral portion of the second thoracic somite is a transverse ridge extending from about the middle of its inner margin to the lateral margin. The posterior margin of this portion is curved forwards, then backwards, so that it does not extend back as far as the middle portion of the segment. Each of the third to seventh thoracic somites has its posterior margin produced in the middle dorsal line to form a spiniform process; those of the third and fourth somites are larger than those of the other somites. The third and fourth somites are sub-equal, the fifth a little longer, and the sixth and seventh each a little shorter than the third. The coxal plates are long, narrow and spiniform, increasing in length from before backwards; those of the seventh thoracic somite extend backwards for some distance beyond the extremity of the terminal segment, and in the largest male in the collection reach a length of 20 mm. and extend backwards in a direction almost parallel with the long axis of the body. The coxal plates of the third, fourth and fifth somites are separated from them by sutures.

The three free abdominal segments each possess a small median dorsal spiniform process on the posterior border; the pleural plates of the second segment are long, extending backwards for some distance beyond the end of the terminal segment; those of the third segment are short, hardly extending beyond the anterior margin of the terminal segment. The terminal segment is slightly broader than long, roughly hexagonal in outline. It has a slight median dorsal keel the length of which is divided into three approximately equal lengths by two spines, the anterior one of which is the larger. On either side of the posterior spine, connected to it by a curved ridge, is a small lateral spine, lying midway between the posterior spine and the lateral margin of the segment. Two small oblique ridges extend from either side of the base of the anterior spine and terminate in small spines on a level with the lateral ones and midway between them and the lateral margins of the segment. The uropoda are attached rather far back on the terminal segment, a little behind the level of the posterior spine; both exopod and endopod are well developed and the latter is the larger.

REMARKS. There is little to add to Beddard's account of this species, but a minor point may be mentioned in connection with the third thoracic appendage of the adult male. Beddard (1884 *b*, p. 59) describes the modified spines which are found on the propodus of this limb, but does not mention that they only occur on the proximal half of the joint, their place being taken distally by a double row of long branched setae similar to those found on the inner margins of the merus and carpus. Similar setae, though not so densely arranged, are found on the inner margins of the carpus, merus and propodus of the last thoracic appendage of the adult male.

DISTRIBUTION. Beddard's specimens were collected at two stations, 42° 32′ S, 56° 29′ W, at a depth of 2040 fathoms, and 37° 17′ S, 53° 52′ W, in 600 fathoms. Those in the present collection come from a locality a little farther to the south-west, between 46°–53° S and 60°–63° W, and from depths of 242–434 m.

24. **Serolis minuta**, Beddard.

S. minuta, Beddard, 1884 *b*, p. 77, pl. vii, figs. 2–7; Whitelegge, 1901, p. 237; Chilton, 1917, p. 397.

S. minuta, Beddard var. *eugeniae*, Nordenstam, 1933, pp. 82–5, pl. i, fig. 3, text-figs. 11 *b*, 20.

DIAGNOSTIC CHARACTERS. The Challenger collection contained a single male measuring 5 mm. in length, and 5 mm. in greatest breadth; the two specimens mentioned by Chilton (p. 397) are both females in the breeding condition, the larger of which measures 8 mm. in length and 7 mm. in breadth. The male is therefore slightly broader in proportion to its length than is the female, and the outline of the body is almost circular.

The head terminates in front in a short rostrum; the posterior margin is provided with three blunt tubercles, the middle of which is the larger. Each of the following thoracic somites has its posterior border produced into a median blunt spine. The third to the seventh somites have well-developed coxal plates and those of the third to the fifth somites are marked off by distinct sutures; lateral tubercles are present on the somites close to their junctions with the coxal plates. The tergum of the seventh somite is partially fused with that of the first abdominal segment, the posterior suture of the former being incomplete for a short space on either side of the middle line.

The pleural plates of the second and third abdominal segments extend beyond the coxal plates of the thoracic somites; those of the third are slightly longer than those of the second and extend to a point just beyond the base of the articulation of the uropod.

The terminal segment is "almost triangular in shape, and ends in a blunt prolongation; the upper surface slopes gently downward on either side from the central keel; the lateral margins, commencing from the attachment of the terminal appendages, curve inwards and then slightly outwards, becoming almost parallel just before their termination". Colour in spirit: brown.

Nordenstam (1933, pp. 82–5) describes a new variety of the above species which he names *eugeniae*. It differs from the main species in the following respects:

(1) "in its more oblong shape of body;

(2) in that the free triangular tips of the pereion segments laterally, from their spimera are lacking;

(3) in having two lateral tuberculae on the pleotelson;

(4) in having the triangular tip in the middle of the posterior margins of the pereion segments missing on the first and second segments".

These differences do not seem sufficient to warrant the formation of a new variety; consequently I have placed the name in the synonymy of *S. minuta*.

OCCURRENCE. Port Philip, Australia, 38 fathoms; and off St Francis Island, from 6 to 13 fathoms.

25. **Serolis bakeri, Chilton.**

S. bakeri, Chilton, 1917, pp. 398, 399, figs. 12–14.

DIAGNOSTIC CHARACTERS. This species, according to Chilton, bears a close resemblance to *S. minuta*, Beddard, but specimens are slightly smaller than those of the latter species, the largest breeding female measuring 6 mm. in length and 5 mm. in breadth: the males are approximately the same size as the females.

As in *S. minuta* three rounded tubercles are present on the posterior margin of the head, but neither the median tubercles nor the lateral tubercles which are seen on the thoracic somites of the former species are found here.

No definite information is given as to whether the coxal plates of the first three free thoracic somites are separated from them by sutures; but since sutures are present in *S. minuta*, and Chilton, after mentioning the points in which the two species differ, states that in all other respects they are alike, it is probably correct to assume that they are also present in this species.

The tergum of the seventh thoracic somite is partially fused with that of the first abdominal segment, the posterior suture of the former being obsolete for a short distance on either side of the middle line. The coxal plates of this somite extend backwards through the anterior third of the terminal segment and the pleural plates of the third abdominal segment reach to the middle of the segment: the terminal segment bears a conspicuous median keel, and its posterior extremity is narrow and rounded. The uropoda are described as having "both branches narrow, outer with external margin obscurely serrate, end dentate or crenate, and with one or two hairs, inner branch a little longer and with end less distinctly serrate".

Nordenstam (1933, p. 85) regards this species as a variety of *S. minuta*, Beddard.

OCCURRENCE. Encounter Bay, South Australian coast.

26. Serolis yongei, Hale.

S. yongei, Hall, 1933, pp. 560–1, 1 text-fig.

Hale's description of this species is extremely short; it is based on two small specimens collected outside Trinity Opening, Low Isles, during the Great Barrier Reef Expedition. Through the kindness of Dr Calman I have been able to examine these specimens, and as a result of my observations am able to amplify the original description in a number of points.

DIAGNOSTIC CHARACTERS. The larger specimen, which is a female in the non-breeding condition with the four pairs of brood plates well developed, measures 2·9 mm. in length and 2·5 mm. in greatest breadth. The shape of the body is described as "wide, pyriform, dorsal surface almost smooth with shallow pitting".

The head is broader than long, about the same width anteriorly as at the level of the eyes, slightly narrower between these two levels; the anterior margin is excavated on either side of a fairly long rostrum for the reception of the antennules. The antero-lateral margins of the head are not completely united with the forward lateral extensions of the second thoracic somite, which is here, as in all species of *Serolis*, fused with the head. The head is roundly convex between the eyes, which are large and are situated on either side in a postero-lateral position. The eyes are reniform and contain black pigment.

The first three free thoracic somites (3rd–5th) are almost sub-equal, decreasing slightly in length from before backwards; the sixth is about half the length of the fifth. The seventh thoracic somite is extremely narrow, with its tergum fused with that of the first abdominal segment for some distance on either side of the median line. Hale makes no mention of this important fact in the text of his paper, but he illustrates it in his figure.

The coxal plates are well developed, and those of the first three free somites are separated from them by sutures (they are not fused as in Hale's figure). Those of the seventh somite are not much more produced than those of the preceding somites; they extend backwards to a point slightly beyond that reached by the pleural plates of the second abdominal segment, at about the level of the bases of the protopodites of the uropods.

The abdominal segments are sub-equal, with the pleural plates of the second and third segments extending for a short distance beyond the broad anterior end of the terminal segment; those of the third segment are slightly the longer, and extend back as far as about the level of the middle of the protopodite of the uropod.

The terminal segment is broader than long, roughly triangular in shape, with the apex directed backwards, and with the angles rounded; it is broadest at the level of the base of the uropods, and has a low median dorsal carina. The sternum of each of the first three abdominal segments is produced into a median backwardly directed spine which is largest on the first segment.

The antennules and antennae have already been described. The form of the antennule is given as "second joint of peduncle nearly half as long again as the fourth, and four times as long as the third, which is very short; flagellum of four joints". This description of the peduncle fits the condition seen in the larger specimen, but in the smaller one the third joint is not much shorter than the fourth; the second is the longest in both specimens. The flagellum consists of six, not four joints. The two distal joints are about half the breadth of those which precede it; the penultimate is short and bears a sensory seta at its anterior distal angle, the terminal is long and bears three long delicate setae at its extremity (cf. a similar arrangement in *S. minuta*, Beddard). A sensory seta is present at the anterior distal angle of each of the third and fourth joints.

According to Hale the two terminal joints of the peduncle of the antenna are subequal; actually, however, the terminal one is considerably longer than the fourth, and is, in fact, slightly longer than the third and fourth together. Groups of delicate setae spring from shallow depressions on the anterior margins of the fourth and fifth joints and one or two delicate plumose setae are also present on the dorsal surface of the fifth joint. The flagellum consists of eight, not six joints. The terminal one is narrow and bears a group of long delicate setae at its extremity; similar setae are present at the anterior distal end of each of the other flagellar joints except the first.

It is impossible to make out any of the structure of the mouth-parts from the specimens. The second pair of thoracic appendages is modified in the usual way: the inner margin of the dilated propodus is armed with a row of three-pronged spines alternating with a row of broad leaf-like structures very similar to, though slightly broader than, the corresponding structures in *S. minuta*, Beddard, which are figured in the Challenger Report (1884, pl. vii, fig. 7). These are flanked by another row of spines, the distal ends of which appear to be covered with very short closely-set hairs. The dactylus bears a strong short spine near the distal extremity of its inner border. The carpus is crenulate and bears two short stout spines, the distal ends of which are obliquely truncate and covered with short hairs; a few more delicate spines similar to those which flank the inner margin of the propodus are also present.

The remaining appendages are all more or less alike, the last pair being somewhat smaller than the rest; the setae on these appendages are all simple, long and delicate (cf. *S. minuta*, Beddard). The protopodite of the first three pairs of pleopods is comparatively long and slender, and, as in the other Australian species, the inner margin is not produced to form a triangular process bearing plumose setae. The suture of the exopod of the fourth pleopod is transverse; short plumose setae are present on its outer margin, at any rate at the distal end. The endopod is considerably smaller than the exopod and has a rounded extremity.

The protopodite of the uropod has its inner angle not much produced; the endopod is longer than the exopod and extends nearly to the tip of the terminal segment. Both lobes are long, with their distal rounded ends sparsely fringed with delicate plumose setae. The colour of the spirit specimen is rather dark brown.

DISTRIBUTION. Outside Trinity Opening, Low Isles, Great Barrier Reef, 16° 17′ S, 146° 2′ E, in 200 m.

The species appears to resemble very closely the two Australian species *S. minuta*, Beddard, and *S. bakeri*, Chilton; the three are together characterized by the facts that (i) the tergum of the seventh thoracic somite is fused with that of the first abdominal segment; (ii) the coxal plates of the three free somites are separated from them by sutures, and (iii) the coxal plates of the seventh somite are comparatively short. In each species the pleural plates of the third abdominal segment extend back farther than do the coxal plates of the seventh thoracic somite.

The form of the antennule is the same in the three species; the second joint of the peduncle is the longest, the penultimate joint of the flagellum very short and the terminal one long and delicate. The form of the modified spines on the inner margin of the propodus of the second thoracic appendage is very much the same in all three species, and in each the setae on the remaining appendages are simple, long and delicate.

If the size of the specimen of *S. yongei* (2·9 mm. long, 2·5 mm. broad) is any indication of that of the adult, this species is considerably smaller than either *S. bakeri* or *S. minuta*. The main difference appears to lie in the ornamentation; the dorsal surface of the body of *S. yongei* is practically smooth and there is only a slight median dorsal carina on the terminal segment, whereas in *S. minuta* there are three tubercles on the posterior part of the cephalosome and one in a median position on each of the thoracic and abdominal segments. In *S. bakeri* the head bears three rounded tubercles on its posterior margin, but these are absent from the thoracic and abdominal segments; the terminal segment bears a conspicuous median dorsal carina and its posterior extremity is narrow and rounded.

The three species are all recorded from the Australian coast; but *S. yongei*, from the Great Barrier Reef, comes from a locality considerably farther north than the other two. *S. bakeri* is recorded from Encounter Bay, South Australia, and *S. minuta* from Port Philip, South Australia, and off St Francis Island.

27. **Serolis orbiculata**, n.sp. (Figs. 1 *b*, *e*, 14, 15).

Occurrence. St. WS 222: 48° 23′ S, 65° 00′ W, 100–106 m.; 1 ♀ (non-b.).
St. WS 808: 49° 40′ 15″ S, 65° 42′ W, 110–107 m.; 1 ♂.
St. WS 809: 49° 28′ 15″ S, 66° 29′ W, 107–104 m.; 1 ♀ (b.).
St. WS 813: 51° 35′ 15″ S, 67° 16′ 15″ W, 106–92 m.; 1 ♀ (b.).
St. WS 815: 51° 51′ 45″ S, 65° 44′ W, 132–162 m.; 3 ♀♀ (b.), 3 (non-b.), and 1 ♂.

DESCRIPTION. The body (Fig. 14) is broadly ovate, not much longer than broad; the male is 8·5 mm. in length and 8 mm. in greatest breadth, and the largest female 10·5 mm. in length and 9 mm. in greatest breadth. The male, as in so many species of *Serolis*, is slightly broader in proportion to its length than is the female.

The surface of the body is smooth, sparsely covered with small microscopic conical-shaped projections. The colour of spirit specimens is brownish towards the centre of the body, paler towards the margins, the whole covered, except for the anterior margins of the somites and their coxal plates, with small spots of black pigment.

The head is convex dorsally, shield-shaped, broader than long, with its greatest breadth anteriorly. The anterior margin is excavated on either side of a short median rostrum for the reception of the antennules, and behind the rostrum is a low transverse ridge extending to the lateral margins of the head. The eyes, which are oval or slightly reniform in shape and contain black pigment, are situated on raised areas towards the postero-lateral angles of the head; the area between the eyes is hollowed out and the lateral portions of the cephalosome are smooth.

The third and fourth (first two free) thoracic somites are sub-equal, the fifth not quite as long, the sixth about half the length of the third; the seventh is fused dorsally with the first abdominal segment for a considerable distance on either side of the middle line.

The coxal plates are well developed, those of the first three free somites are separated from them by sutures; those of the seventh somite extend backwards to about the middle of the protopodite of the uropod and just beyond the middle of the terminal segment: those of the male are very slightly longer than those of the female.

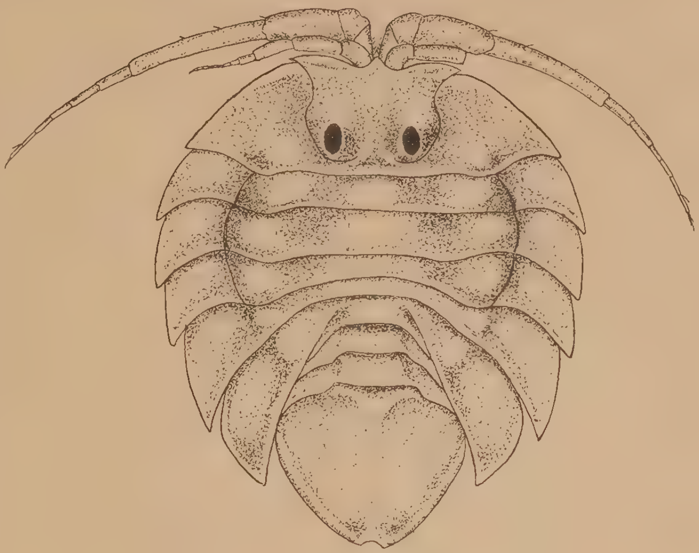

Fig. 14. *Serolis orbiculata*, n.sp., ♀: × 10.

The first three abdominal segments are broad, with a length equal to that of the fifth thoracic somite; the pleural plates of the second and third segments are short and do not extend beyond the anterior margin of the broad terminal segment. Each of the sternal plates of these segments has the median posterior border produced into a small spine, increasing in length from the first to the third. The terminal segment is triangular in shape, with the angles approximately equal and well rounded, and with the apex directed backwards; on its dorsal surface is an ill-defined median dorsal carina, on either side of which, placed at some distance from it, is a short lateral carina. This is made more conspicuous by the presence of a line of deeper pigmentation.

The antennule is less than half the length of the antenna; it consists of a peduncle of four and a flagellum of eight joints. The first peduncular joint is short; the second and third are both about twice the length of the first, whilst the fourth is shorter, being only about one-third the length of the third: the second and third joints are sparsely fringed with delicate setae. The flagellum consists of seven joints of about equal length, but narrowing distally, and a very minute terminal joint which bears a single sensory and several simple setae; a sensory seta is present at the anterior distal angle of all except the first two joints of the flagellum.

The antenna consists of a peduncle of five and a flagellum of six joints. The first peduncular joint is short, broader than long, with its inner border fringed with short hairs; the fourth joint is about three times the length of the second, and the fifth over twice as long as the fourth; bundles of fine setae arising from round knob-like bases are scattered over the ventral surfaces of the third, fourth and fifth joints. The flagellum is not much longer than the fifth peduncular joint; its first two joints are sub-equal and twice as long as each of the remaining four; the terminal joint bears a bunch of fine setae at its extremity.

The mouth-parts are built up in the normal way. The cutting edge of the left mandible has its primary edge divided into three teeth; the secondary one is in the form of two spines, one of which is truncate with a broad rounded extremity: the secondary cutting edge of the right mandible is in the form of two spines, the inner one of which is larger than the outer.

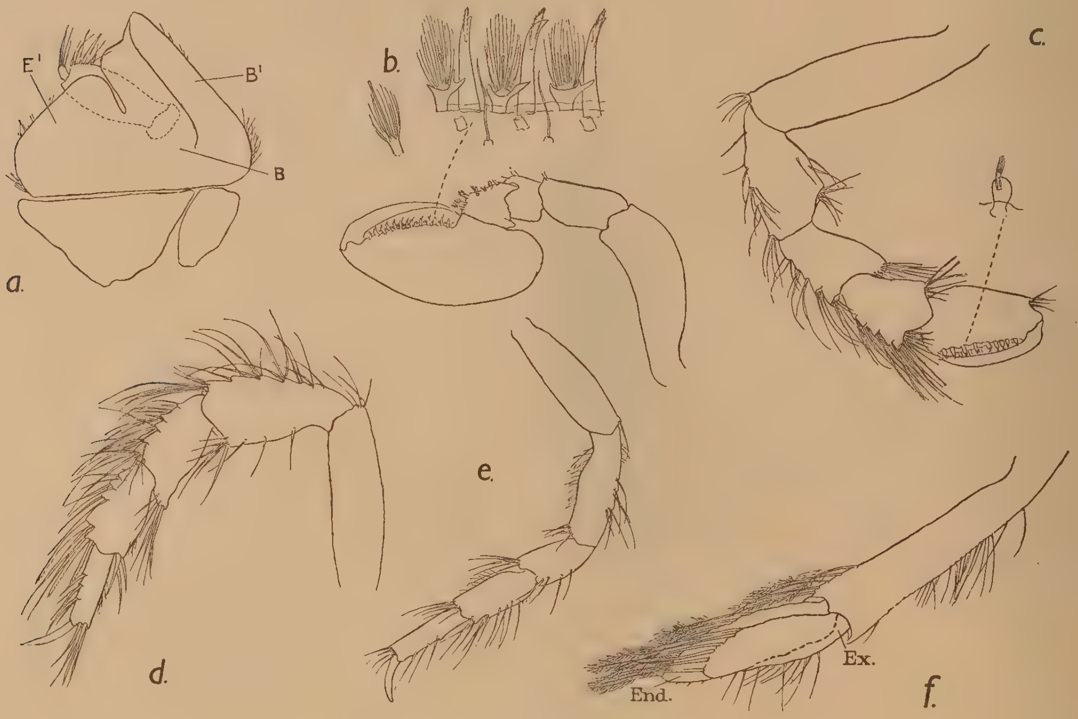

Fig. 15. *Serolis orbiculata*, n.sp.

a, maxilliped of ♂: × 75. *b*, second thoracic appendage of ♂: × 35. *c*, third thoracic appendage of adult ♂: × 50. *d*, fourth thoracic appendage of ♂: × 50. *e*, eighth thoracic appendage of ♂: × 60. *f*, uropod: × 50.

The maxillula (Fig. 1 *b*) has nine spines on the truncate extremity of its outer lobe; its inner lobe is small, curved, not expanded distally, and with a small seta at its rounded end. The maxilla (Fig. 1 *e*) resembles that of *S. nototropis*, n.sp., and differs from that of all other species in having only one articulating lobe. This lobe (L^3) is less well developed than in *S. nototropis* and bears only two pectinate setae. The lobe is continuous with the segment from which it arises, and the latter appears also to be continuous with the lamella of the second segment (L^2): in some preparations a faint line, shown by the dotted line in the figure seems to indicate the boundary of the plate-like portion of the second segment (for discussion on the morphology of this appendage see p. 272).

The maxilliped (Fig. 15 *a*) closely resembles the type seen in *S. nototropis*, in which the union of the basipodite with its endite (B') and lamella (E') extends for some distance beyond the base of the endopod, the latter springing from the centre of a plate-like structure. The groove separating the endite (B') from the lamella (E') is slightly deeper than that of *S. nototropis*. The endopod consists of the usual three joints; the second is almost parallel-sided, narrowing slightly towards its distal end, the third joint is small and both are fringed with setae along their inner margins. The forms of the second, third, fourth, and last thoracic appendages of the male are shown in Figs. 15 *b–e*. The second is stout, with the propodus expanded and bearing a row of about fourteen modified spines alternating with peculiar processes, the form of which is shown in Fig. 15 *b*. This row is flanked by another row of modified spines of the type shown in the figure, and beyond these, and alternating with them, is a row of simple setae. The distal edge of the carpus is crenulate and bears three setae in form similar to, but smaller than those flanking the row on the propodus. The third thoracic appendage (Fig. 15 *c*) is considerably longer than the second; the propodus is broad and has its inner margin armed with a double row of nine modified spines; the other joints of the appendage, as well as those of the remaining ones, bear a series of short transverse rows of long setae, some of which, towards the distal ends of the merus, carpus and propodus, are pectinate. The last appendage, in both sexes, only differs from the remaining ones in being smaller.

The protopodite of the first three pairs of pleopods is not produced as is usually the case; both margins are fringed with long delicate setae. The appendix masculina on the second pleopod of the male reaches three-quarters of the way towards the apex of the terminal segment. The exopod of the fourth pleopod is divided by a transverse suture; it is fringed with long plumose setae on its outer margin.

The protopodite of the uropod (Fig. 15 *f*) is exceptionally long, being considerably longer than the endopod; its inner distal angle is not produced as is usually the case. The exopod and endopod are narrowly oval in shape, the latter being longer than the former; both are fringed along their inner margins with long plumose setae, which are continued for a short distance on to the margin of the protopodite. The outer margins of both the protopodite and the exopod are fringed with delicate setae.

This species resembles most closely *S. nototropis*, n.sp., but can be readily distinguished from it by the shape of the body and terminal segment, by the form of the modified spines on the propodus of the second thoracic appendage, as well as by the difference in length of the protopodite of the uropod. The two species resemble each other and differ from all other species in the form of the maxilliped, and the absence of the second articulating lobe in the maxilla.

Distribution. The species occurs off the coast of South America to the north-west of the Falkland Islands, in depths of from 92 to 162 m.

28. Serolis nototropis, n.sp. (Figs. 1 *d*, 16, 17).

Occurrence. St. WS 796: 47° 49′ 37″ S, 63° 42′ 30″ W, 106 m.; 3 ♀♀ (b.).
St. WS 797: 47° 45′ 18″ S, 64° 10′ 30″ W, 117 m.; 1 ♀ (b.).
St. WS 813: 51° 35′ 15″ S, 67° 16′ 15″ W, 106 m.; 1 ♀ (b.), 2 immature ♂♂.
St. WS 815: 51° 51′ 45″ S, 65° 44′ W, 132–162 m.; 1 ♂.
St. WS 816: 52° 09′ 45″ S, 64° 56′ W, 150 m.; 1 ♀.
St. WS 837: 52° 49′ 15″ S, 66° 28′ W, 98 m.; 1 ♂.

Description. The body (Fig. 16) is longer than broad, almost oval in shape, but narrowing posteriorly; the dorsal surface is arched, with a pronounced median keel which is better developed in the male than the female. The surface of the body is slightly pitted and covered with rows of conical papillar projections (Fig. 17 *a*). The only adult male measures 11 mm. in length and 8 mm. in greatest breadth, the largest female 12 mm. in length and 9 mm. in greatest breadth, so that in this species the ratio of length to breadth is approximately the same for the two sexes.

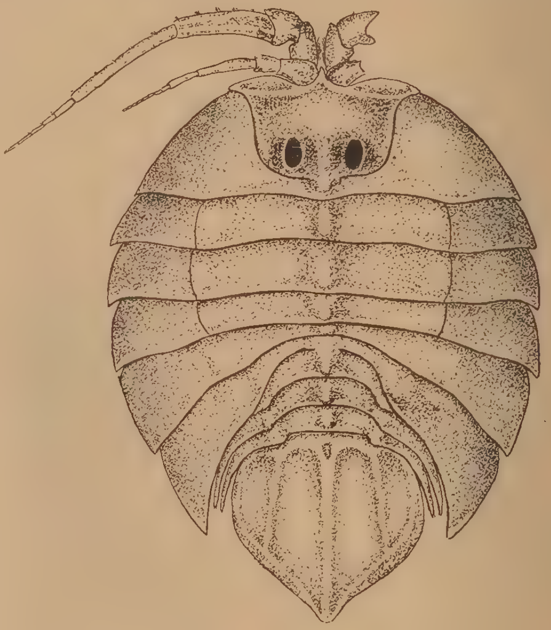
Fig. 16. *Serolis nototropis*, n.sp., ♀: × 10.

The head is broader than long, shield-shaped, with the greatest width anteriorly. A short rostrum is present, on either side of which the anterior margin is excavated for the reception of the antennules, and immediately behind this margin a transverse ridge extends across the width of the head. The eyes, which are situated on raised areas, are placed rather close together near the posterior border of the head; the area of the latter between the eyes and the anterior transverse ridge is raised. The eyes are small, oval in shape, and contain black pigment.

As in all the Serolidae the second thoracic somite is fused with the head; the lateral portion is smooth, but in the middle line, behind the head, the surface is raised into a small dorsal spiniform process. The third and fourth thoracic somites are sub-equal, the fifth and sixth are together equal to the third, whilst the seventh is equal to the sixth but is fused with the first abdominal segment for a short distance on either side of the middle line. Small median spiniform processes, decreasing in size from before backwards, are present near the posterior borders of the third, fourth and fifth somites. The coxal plates of the third to the seventh somites are well developed and those of the third, fourth and fifth are separated from their respective somites by sutures; in both sexes those of the seventh somite are more produced than those of the other somites and extend backwards to about the level of the base of the uropod.

The abdomen consists of three free segments and a large terminal one. Each of the first three is slightly keeled and bears a small spiniform process corresponding in position with those of the thoracic somites; the pleural plates of the second and third abdominal segments are well developed, but do not extend backwards quite so far as the coxal plates of the seventh thoracic somite; those of the third segment are slightly the longer. Each of the sternal plates of these segments has the median posterior border produced into a spine, increasing in length from the first to the third.

The terminal segment (Fig. 16) is roughly triangular in shape, with the apex directed backwards and with the basal angles broadly rounded. On its dorsal surface is a strong median carina which extends to the end of the upturned posterior extremity; this carina is broadest anteriorly where there is a small oval pit in a median position on its dorsal surface. Two pairs of lateral carinae are also present; one on either side runs parallel with the lateral margin of the segment but a short distance within it; the other lies almost midway between the latter and the median carina, with which it runs almost parallel, meeting the outer lateral carina at a point level with the posterior end of the coxal plate of the seventh thoracic somite.

The antennule is short and consists of a peduncle of four joints, and a flagellum, which in the male comprises ten joints, in the female seven. The first peduncular joint is not much longer than broad; the second is about the same length with its postero-distal angle slightly produced; the third joint is more than twice as long as the second, broad proximally, but narrowing distally; the fourth is about half the length of the third. The flagellum is not quite as long as the third peduncular joint; its joints, except for the terminal one, which is minute, are all of approximately the same size: the third to the tenth each bear a sensory seta of the usual type, placed near the anterior distal angle.

The antenna is nearly twice as long as the antennule: both the peduncle and the flagellum consist of five joints. The first joint of the peduncle is short, broader than long; the second is about three times the length of the first, with its anterior distal angle produced, and with the proximal part of the anterior margin covered with short hairs; in the third peduncular joint the anterior margin is equal in length to that of the second joint, but with its posterior margin curved, and considerably shorter; this joint is broadest distally, has its anterior distal angle somewhat produced, and short hairs are present on its posterior margin. The fourth peduncular joint is twice the length of the third, with a dorsal longitudinal ridge extending along its upper surface near the posterior margin; the fifth joint is nearly twice as long as the fourth but considerably narrower. On the ventral surfaces of the third, fourth, and fifth joints is a series of short transverse rows of setae which are arranged in bundles; each bundle consists of about five long delicate setae arising from a common basal "knob", and the transverse rows, each of which contains three or four of these bundles, extend from about the middle of the ventral surface as far as the anterior margin. There are two transverse rows on the third, five on the fourth and seven on the fifth joint.

The mandibles are built on the usual plan and their cutting edges are comparatively simple; that of the right mandible is divided into four by three shallow notches, with the secondary blade in the form of a single toothed spine. The cutting edge of the left mandible is narrower than that of the right and is undivided; its inner secondary blade is in the form of two spines, the larger one of which has a bifid extremity.

The outer lobe of the maxillula bears ten stout spines, and a single more slender pectinate one, on its truncate distal extremity. The maxilla (Fig. 1 *d*) differs from that of all the other species of *Serolis* except *S. orbiculata*, n.sp., in possessing only one articulating lobe instead of two. This lobe bears four pectinate setae at its distal extremity, and fourteen similar setae are present on the distal end of the fixed lobe. There appears to be no suture between the third joint of the primary axis and the lamella of the second joint (for discussion on the morphology see p. 272).

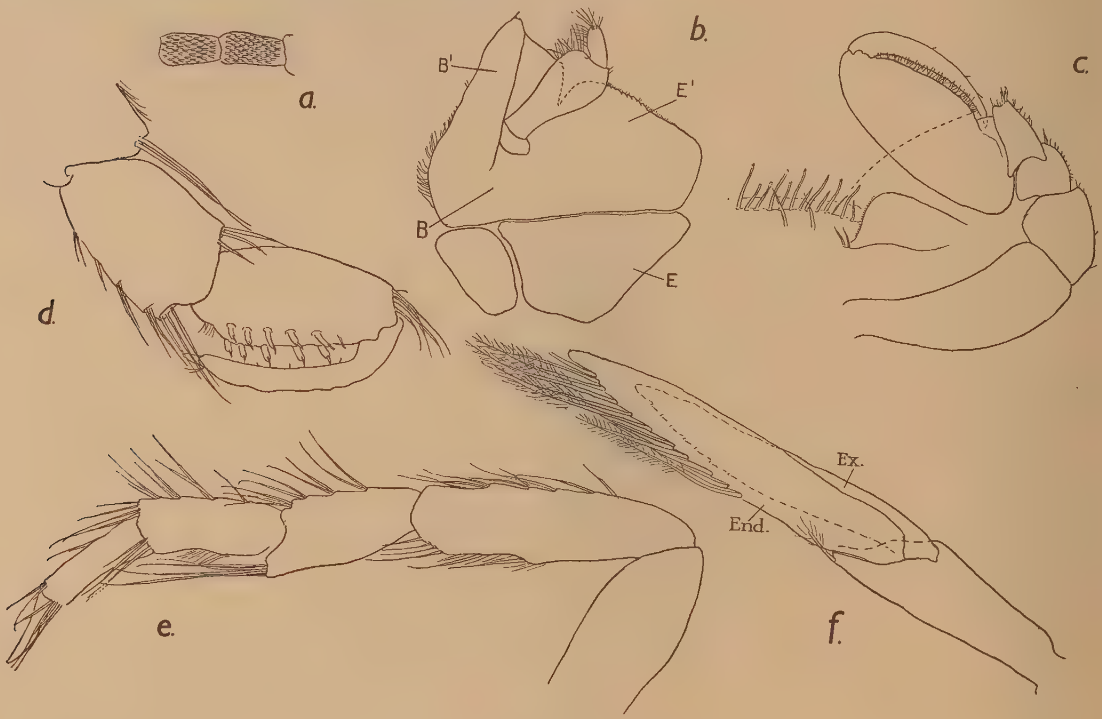

Fig. 17. *Serolis nototropis*, n.sp.

a, two joints of the antennal flagellum, to show the conical scales. *b*. maxilliped of ♂: × 50. *c*, second thoracic appendage of ♂: × 64. *d*, third thoracic appendage of ♂: × 90. *e*, fourth thoracic appendage of ♂: × 67. *f*, uropod: × 83.

The type of maxilliped met with in this species (Fig. 17 *b*) is intermediate between that of *S. exigua*, Nordenstam, and that of *S. schythei*, Lütken. The endopod springs from the middle of a plate-like structure consisting of the basipodite (*B*) plus its endite (*B'*) and its lamella (*E'*): distally the endite and the lamella are separate for a short distance, but the division does not extend as far as the articulation of the endopod. The endopod is comparatively slender, and its distal joint is small and fringed on its inner margin with long setae; similar setae are also found on the distal half of the inner margin of the second joint.

The form of the second, third and fourth thoracic appendages is shown in the figures (Fig. 17 *c–e*). The second appendage is stout; the propodus is oval in shape, and bears on its inner margin a row of about thirty-six rather delicate spines which appear to be simple but with a high magnification show fine, short pectinations near their distal ends. The spines are of two lengths, the longer being slightly stouter and alternating with the shorter type. The species agrees with *S. exigua* and differs from all other species in having only one variety of modified spine on this joint. At the proximal end, the inner surface is considerably raised into a median prominence, and its steep face (towards the distal end of the joint) is covered with very short hairs; the dactylus extends for some distance beyond the flat face of this raised area.

The distal truncate extremity of the carpus bears two stout spines, each with a bifid extremity, and three or four delicate setae. The third appendage of the male (Fig. 17 *d*) is longer but less robust than the second. The propodus is broad and its inner margin is armed with a double row of five modified setae of the usual type; near its proximal end is a small group of short hairs and at the outer angle of its truncate distal extremity is a group of five long setae: the dactylus terminates in a stout spine at the base of which are a few short hairs. The setae present on the remaining joints as well as those of the other appendages are long, usually simple, and arranged in short transverse rows in notches on the margins of the joints (Fig. 17 *e*). The last thoracic appendage is similar in the two sexes; it is shorter than the others, and its joints are relatively broader in proportion to their length.

The protopodite of the first three pairs of pleopods is somewhat triangular in shape with the produced angle bearing long plumose setae; there are three of these on the first and two on each of the second and third pleopods. The appendix masculina on the second pleopod of the male reaches about two-thirds of the way towards the apex of the terminal segment. Both the exopod and endopod of the fourth pleopod are divided by a transverse suture; the outer margin of the exopod is fringed with plumose setae.

The protopodite of the uropod (Fig. 17*f*) is rather long, with its inner angle produced and bearing a short plumose seta; the exopod is shorter than the endopod, and both are fringed along their inner margins with long plumose setae which, however, do not extend quite to their distal ends.

DISTRIBUTION. This species was collected from localities north and west of the Falkland Islands, in water from 98 to 150 m. in depth.

29. Serolis pagenstecheri, Pfeffer.

S. pagenstecheri, Pfeffer, 1887, p. 73, pl. ii, figs. 1, 2, pl. iv, figs. 1–3; Tattersall, 1921, p. 231; Monod, 1931, p. 26; Nordenstam, 1933, pp. 85–8, text-figs.

S. pagenstecheri var. *albida*, Nordenstam, 1933, pp. 88–9, pl. i, figs. 4, 5, text-fig. 21 *e*.

Occurrence. St. 39: South Georgia, 179–235 m.; 1 ♀ (b.), 2 ♂♂ (immature).
St. 42: South Georgia, 120–204 m.; 1 ♀ (b.); 2 ♀♀ (non-b.), 2 immature ♂♂, and a number of small specimens.
St. 140: South Georgia, 122–136 m.; a number of immature specimens.
St. 144: South Georgia, 155–178 m.; 4 immature specimens.

St. 149: South Georgia, 200–234 m.; 1 immature specimen.
St. 157: South Georgia, 970 m.; 1 ♀ (b.).
St. WS 62: South Georgia, 26–83 m.; 2 ♀♀ (b.), 2 ♂♂, 4 immature specimens.
St. MS 10: East Cumberland Bay, 26 m.; 2 ♀♀ (non-b.), 3 immature specimens.
St. MS 67: East Cumberland Bay, 38 m.; 1 immature specimen.
Beach, Grytviken, South Georgia; 1 ♀ (non-b.).

DIAGNOSTIC CHARACTERS. The largest male in the collection measures 37 mm. in length and 34 mm. in greatest breadth; it is slightly broader in proportion to its length than the female, the largest of which measures 38 mm. in length and 32 mm. in breadth. The colour of the living animal is given as dark grey above and white beneath, with the gonads often showing through as orange-red masses.

The body is broadly ovate, with its dorsal surface covered with scattered hairs which are most numerous along the margins of the segments. The head is broadest anteriorly, with a short median rostrum, behind which is a transverse ridge extending laterally to the sides of the cephalosome. Behind this again is another transverse ridge extending between and in a line with the anterior end of the eyes; it is lower in the middle than at the sides and immediately posterior to it is a deep groove. The portion of the head between the eyes is strongly convex, and divided into three prominences: in these the posterior margins are much more sharply defined than the anterior which gradually merge into the surface of the head. The lateral prominences are oval and larger than the central one, the latter being in the form of a triangle with the apex directed forwards. The eyes are about half the length of the head, rather narrow, reniform in shape, and containing black pigment.

The lateral portion of the second thoracic somite, which is fused with the head, has a transverse ridge on each side, commencing at a point in line with the middle of the length of the eye, and running transversely and then slightly backwards, fading away into the lateral margins; a second short ridge, commencing on either side on the anterior transverse ridge, half-way along the course of the latter on the cephalosome, extends backwards and slightly outwards for a short distance.

The first three free thoracic somites are sub-equal, with their posterior borders slightly raised to form small median spiniform processes which increase in size from before backwards. The sixth and seventh thoracic somites are narrow, together equal to the preceding one; the posterior border of the seventh is obsolete in the middle line, so that for a short distance the tergum of the seventh somite is fused with that of the first abdominal segment. The third to the seventh thoracic somites have well developed coxal plates, each of which bears a well marked groove which follows the outline of its anterior margin a short distance within it. The coxal plates of the first three free somites are separated from their respective somites by sutures: those of the seventh somite are produced backwards beyond the pleural plates of the abdominal segments to a point just beyond the level of the articulation of the uropods; they are longer in the male than in the female.

Each of the three free abdominal segments has a short median dorsal spiniform process; the pleural plates of the third segment extend backwards to the level of the articulation of the uropods, and those of the second somite are shorter than those of the third. The terminal segment is roughly five-sided, with rounded angles and with a truncate posterior extremity. It has a well developed spine in the anterior mid-dorsal line, followed by a low median keel which is more pronounced towards the posterior extremity; on each side of this keel are two lateral longitudinal keels, terminating in small spines some distance from the lateral margins which are slightly bent downward. The uropods do not extend to the tip of the terminal segment: the exopod is about two-thirds the length of the endopod; both are elongated oval in shape, with their margins fringed with long plumose setae.

Remarks. The mouth-parts are of the normal type. The outer lobe of the maxillula bears eleven spines on its distal extremity: the inner lobe differs from the usual type in having the distal third of its length much expanded so as to be almost circular in outline; it bears a single small curved spine. The lamella of the maxilliped is separated from the basipodite by a suture. A point not previously noted in this appendage is that at the distal outer extremity of the third joint of the palp there is a groove in which a very small fourth joint is articulated. This joint does not extend quite as far as the distal end of the third, and it carries five long setae on its truncate extremity. A similar joint has been observed on the maxillipeds of *S. kempi*, n.sp., and *S. platygaster*, n.sp. (Fig. 19 *a*). The modified spines on the propodus of the second thoracic appendage are very similar to those figured for *S. beddardi*, Calman (Fig. 3 *b*).

According to Pfeffer the third thoracic appendage of the male "resembles those of the following segments and does not show the cheliform formation present in other species; the only outstanding character is the slightly vigorous formation of the penultimate joint". It is obvious that the males in Pfeffer's collection were all immature, for in the adult male this appendage shows a typically cheliform structure. The propodus is broad and bears on its inner border a double row of eleven strong curved spines, each of which is covered with dense short hairs; the axis of the spine extends beyond the hairs as a delicate curved process and between these spines are a few simple setae. The inner border of the carpus, merus, ischium and distal half of the basipodite is densely clothed with short fine hairs. Similar hairs occur on the propodus, carpus, merus and ischium of the eighth thoracic appendage of the adult male; they are found on both inner and outer margins, but are more abundant on the former; in the latter position, on the merus and the ischium, they are restricted to the distal half. The joints of this appendage are broader in proportion to their length than those of the other appendages.

Nordenstam (1933, p. 88) describes a new form of *S. pagenstecheri*, a variety *albida*. The variety is smaller in size than the typical form, and of "slightly yellowish, almost whitish" colour. The only other difference between this and the typical species is that "the male has a slightly more oblong shape of body than the main species". The shape of the female is the same in both forms. The differences in size and colour are not sufficiently dependable characters on which to base the formation of even a variety, and since the shape of the female is the same in both I am unable to admit the validity of the varietal name *albida*.

Distribution. Pfeffer's and Tattersall's specimens came from South Georgia, as do those in the present collection.

30. Serolis platygaster, n.sp. (Figs. 18, 19).

Occurrence. St. 146: 53° 48′ 00″ S, 35° 37′ 30″ W, 728 m.; 1 adult ♂.

Description. The specimen (Fig. 18) measures 33 mm. in length and 27 mm. in greatest breadth; it is broadly ovate in outline and compact in form. The head is broadest anteriorly and widens in front of the eyes, the distance between the eyes being three-fifths of the length of the anterior margin. A small but distinct rostrum is present; a short distance behind it is a transverse ridge which meets the boundary of the head midway between the eyes and its anterior margin. On either side of the rostrum, the anterior margin is excavated for the reception of the base of the antennule and a groove running within the margin extends laterally to the sides of the head. Behind the transverse ridge, and between it and the eyes, the middle portion of the head is convex, whilst the area between the eyes is also raised and divided into two large rounded prominences, the posterior margins of which are better defined than the anterior. In an anterior position between these prominences is a small triangular area, with its apex directed backwards, which is more deeply pigmented than is the rest of the body. The eyes are very small in proportion to the size of the body, postero-lateral in position, about a third of the length of the head, and very narrow; they contain black pigment.

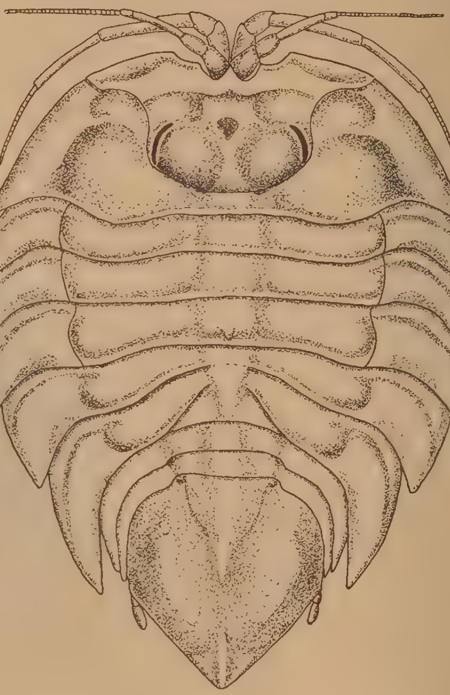

Fig. 18. *Serolis platygaster*, n.sp., ♂: × 4.

As in all Serolidae, the second thoracic segment is united with the head. The lateral portion bears a low ridge extending from near the posterior angle of the eye; it runs first in a transverse direction outwards, and then branches, with one branch curving forwards and disappearing on the antero-lateral margin of the head, the other curving backwards, running almost parallel with but some distance from the margin of the cephalosome, and disappearing near the posterior border. The third, fourth, and fifth thoracic somites are sub-equal, slightly keeled, with the fifth somite raised near its posterior margin into a small median dorsal protuberance. The sixth and seventh somites are sub-equal, together equal in length to the preceding somite: the posterior sutures of the terga of both somites are absent for a short distance on either side of the mid-dorsal line, so that for a short distance they are fused with each other and with the first abdominal segment; the position of the former suture between the two thoracic somites is indicated by a slight groove. In this respect the species agrees with the condition seen in the female of *S. aspera*, n.sp. (in the male the groove is absent), and is intermediate between *S. pagenstecheri*, Pfeffer, where only the suture between the seventh thoracic and first abdominal segment is obsolete, and *S. bouvieri*, Richardson, and the male of *S. aspera*, where fusion is complete and no groove indicates the position of the former suture. The coxal plates, which are rather short and closely applied together for their whole length, are developed on each of the third to the seventh thoracic somites; those of the third to the fifth are separated from their respective somites by sutures. A low prominence is present on either side of each somite near its posterior border and just within the point of union with it and its coxal plate: a groove is present on the dorsal surface of each coxal plate, running parallel with, though a little distance within its anterior margin. Long delicate setae fringe the inner lateral margins of both the coxal and pleural plates. The coxal plates of the seventh thoracic somite extend back to a level corresponding with that of the bases of the uropoda, and slightly beyond that reached by the pleural plates of the third abdominal segment. The pleural plates of the second abdominal segment are a little shorter than those of the third.

The terminal segment is somewhat pentagonal in outline, terminating posteriorly in a blunt point which is slightly uptilted. The base of the pentagon also forms the base of a somewhat raised, triangular area, which bears a low median keel and extends to about the middle of the segment; the posterior quarter is also slightly keeled. Two longitudinal ridges, one on either side, lie near the lateral margins of the segment.

The peduncle of the antennule is four-jointed; the first two joints are small, the third one and a half times the length of the second, the fourth about a third of the length of the third. Delicate setae are present on the anterior margin of the first joint and along the anterior and posterior margins of the second and third joints. Neither flagellum is complete, but one consists of twenty-five joints, the first eight of which do not bear sensory setae.

The first peduncular joint of the antenna is short; the second is three times the length of the first and is fringed with delicate setae; the third is about two-thirds the length of the second with tufts of setae on its posterior margin; the fourth and fifth are each three times the length of the third, the fifth being narrower than the fourth. The incomplete flagellum consists of fourteen joints.

The mandibles are of the usual type; the primary cutting edges of both are strongly chitinized. The maxillula is of the usual type, with a stout outer lobe bearing eight stout spines and an inner more delicate one on its obliquely truncate distal extremity. The inner lobe is two-thirds the length of the outer and is flattened distally to form an oval plate, the outer margin of which is more curved than the inner. The distal ends of both outer and inner articulated lobes of the maxilla are provided with two strong setae which are minutely pectinate on their inner margins; the fixed lobe has eight large and about twelve smaller setae at its distal end.

The basipodite of the maxilliped (Fig. 19*a*) is separated from its lamella, which is slightly broader than long, by a suture. The second joint of the palp is broadest distally, with its inner margin fringed with setae; the third joint is more or less parallel-sided, with its inner distal end rounded and fringed with setae. Near the extremity of this joint, at its outer angle, is a fourth small joint; the distal extremity of this joint does not extend beyond that of the third, and it is truncate, bearing six long setae. Similar joints are present in a corresponding position on the maxillipeds of several other species.

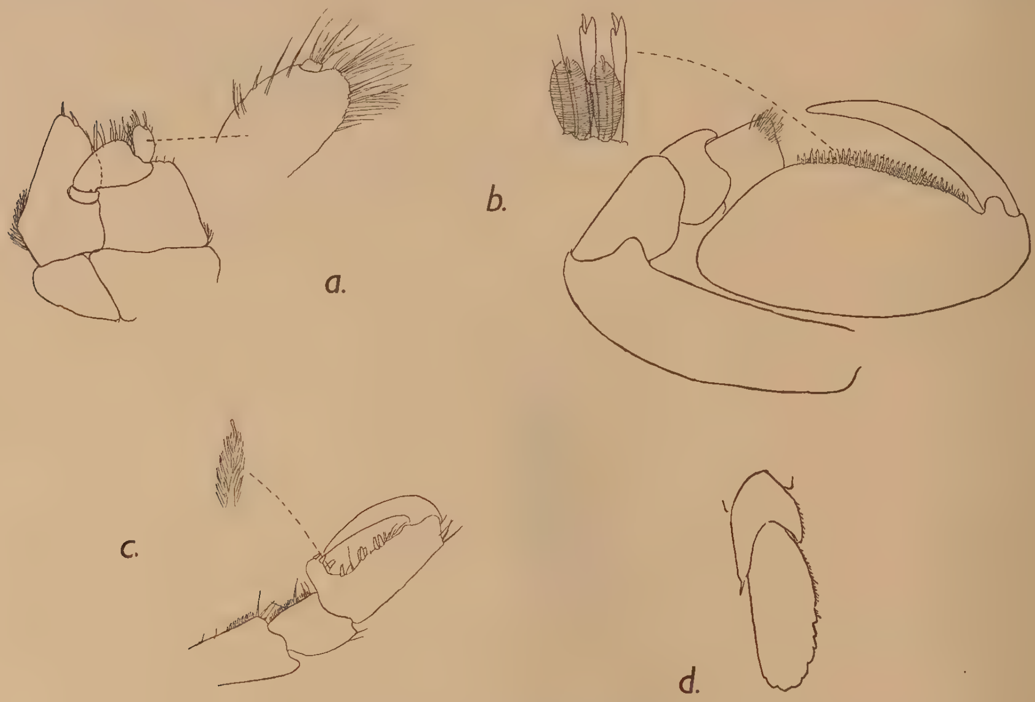

Fig. 19. *Serolis platygaster*, n.sp.
a, maxilliped: × 14. *b*, second thoracic appendage: × 14. *c*, third thoracic appendage of ♂: × 14. *d*, uropod: × 24.

The second thoracic appendage has its propodus greatly expanded, with its inner margin armed with a row of about thirty-five broadly oval processes alternating with modified spines (Fig. 19 *b*). As is usual in the adult male the third thoracic appendage is modified (Fig. 19 *c*). The proximal angle of the expanded propodus is produced so that the inner margin appears to be considerably hollowed out; this margin is armed with a double row of modified spines (see figure), three pairs of which are situated on the inner surface of the produced angle, whilst a further six pairs are arranged along the remaining part. The dactylus is shorter than the propodus and terminates distally in two short spines, one of which is larger and stronger than the other; the inner margins of the carpus and merus are densely fringed with short hairs. Most of the thoracic appendages are incomplete, the last does not differ except in size from those that precede it.

The protopodite of the first three pairs of pleopods is triangular in shape with the produced angle bearing plumose setae, three on the first, and two on the second and third. The appendix masculina on the second pleopod reaches about two-thirds of the way towards the apex of the terminal segment. The suture of the exopod of the fourth pleopod is slightly oblique and the outer border is fringed with plumose setae; the endopod is not divided by a suture, and does not bear setae; a suture extends for a short distance across the exopod of the fifth pleopod.

Unfortunately the right uropod is damaged, but if the left is complete, as it appears to be (Fig. 19 *d*), it resembles that of *S. beddardi*, Calman, and *S. latifrons*, White, in the absence of the endopod. It differs from them, however, in having the protopodite and its produced spine short, not produced into a long spiniform process. The exopod is very small, oval in shape and 1·5 mm. in length, with its outer margin and rounded end notched and bearing a few delicate setae.

This species most closely resembles *S. bouvieri*, Richardson, but can be readily distinguished from it by the fact that in the latter the outer edges of the coxal and pleural plates and also the margins of the terminal segment are greatly thickened, and that the posterior region of the head is raised into two prominent tubercles which meet in the middle line. In the latter species, also, the eyes are well developed and contain black pigment, whereas in the former the eyes are small and very narrow.

DISTRIBUTION. 53° 48′ 00″ S, 35° 37′ 30″ W, north-east of South Georgia.

31. **Serolis bouvieri**, Richardson (Fig. 20).

S. bouvieri, Richardson, 1906 *a*, p. 7, text-figs. 12, 13, pl. i, fig. 1; Nordenstam, 1933, pp. 89–90, text-figs. 5 *a*, 11 *a*.

Occurrence. St. 181: Palmer Archipelago, 160–335 m.; 2 immature specimens.
St. 190: Palmer Archipelago, 93–130 m.; 1 adult ♂ and 1 ♀ (non-b.).
St. 190: Palmer Archipelago, 315 m.; 1 ♀ (non-b.).
St. 195: South Shetlands, 391 m.; 1 adult ♂, 16 immature specimens.

DIAGNOSTIC CHARACTERS. The body is oval, longer than broad, with the whole surface covered with scattered shallow pits. On either side of the long rostrum the head is excavated for the reception of the antennules, and the posterior region is raised into two prominent tubercles which meet in the middle line. The eyes are placed one on the outer side of each tubercle; they are reniform in shape and contain black pigment.

The postero-lateral angles of the coxal plates of the thoracic somites are produced backwards and have their distal ends rounded and thickened, a thickening which gives the species a very characteristic appearance. The terga of the first three free thoracic somites are separated by sutures from their respective coxal plates; the terga of the sixth and seventh thoracic somites are fused with each other and with the tergum of the first abdominal segment in the mid-dorsal line.

The terminal segment is a little broader than long, with its greatest width towards the middle of the segment; it narrows posteriorly to about a third of its width. The rounded postero-lateral angles are thickened and are produced for about 1·5 mm. beyond the central tip of the segment, the median dorsal carina of which extends as a short projection. In some specimens a small lateral carina is present, one on either side of the median; this is less noticeable in large specimens. The uropoda are very small, but both exopod and endopod are developed. In the male the coxal plates of the seventh thoracic somite extend posteriorly to a short distance behind the attachment of the uropod; in the female they are not as long: in both sexes they extend beyond the pleural plates of the second abdominal segment, but in the female they only reach as far as the extremities of the third.

REMARKS. The specimens were collected to the south of the South Shetland Islands at depths of from 93 to 335 m.; the largest adult male measures 41 mm. in length and 31 mm. in breadth and is considerably larger than any of Richardson's specimens. The largest specimen, which was collected at a depth of 20–40 m., measures 35 mm. in length and 25 mm. in breadth.

The appendages, with the exception of the antennule and the antenna, are not described in the original paper: a few additional observations are therefore included here.

The antennule (Fig. 20 *a*) consists of a peduncle of four and a flagellum of thirty-six joints. The first joint of the peduncle is geniculate, and bears on its dorsal surface a well-marked ridge, which has its anterior distal angle produced into a strong spiniform process. The second joint is two-thirds the length of the first and has a similar dorsal ridge, which, however, is produced to form two more processes, one midway along its posterior margin, and the other, on its anterior margin, slightly nearer the distal extremity. The third joint is about equal in length to the first, but is slightly curved and only half its width; the fourth is a quarter the length of the third and is broader at its distal than at its proximal end. Long delicate hairs are present on the anterior margins of the first two, and on the posterior of the second peduncle joints. The first joint of the flagellum is about half the length of the last peduncular joint; the second and succeeding joints are half the length of the first, the length increasing towards the distal end of the flagellum; the terminal joint is equal in length to the penultimate, but is only half its breadth. A sensory hair is present at the distal end of each of the last twenty joints.

The antenna is made up of the usual five peduncular joints and a flagellum of nineteen. The first joint of the peduncle is short; the second is three times the length of the first with short hairs on its anterior margin, whilst the third is the same length as the first. A rounded tubercle is present on the dorsal surface at the distal end of both second and third joints and is larger on the former than the latter. The fourth and fifth joints are each twice as long as the second, but the fourth is considerably broader than the fifth; the flagellum is one and a half times as long as the fifth joint of the peduncle.

The mouth-parts are of the usual type; the form of the cutting edges of the mandibles may be seen from Fig. 20 *b*. The outer lobe of the maxillula bears ten stout spines and an inner, more delicate, pectinate one on its truncate distal extremity. There are two pectinate setae on the outer, three on the inner and about fifteen on the fixed lobe of the maxilla.

The basipodite of the maxilliped is separated by a suture from the lamella. The second joint of the palp is broad; the inner and outer margins of the third joint are almost parallel, but at about one-quarter of the distance from the distal end, the outer margin is notched for the reception of a fourth joint which is short and narrow, not extending to the end of the third joint and bearing six long setae at its distal end. A corresponding joint is found on the palp of *S. platygaster*, n.sp. (Fig. 19 *a*), *S. pagenstecheri*, Pfeffer, and *S. gerlachei*, Monod.

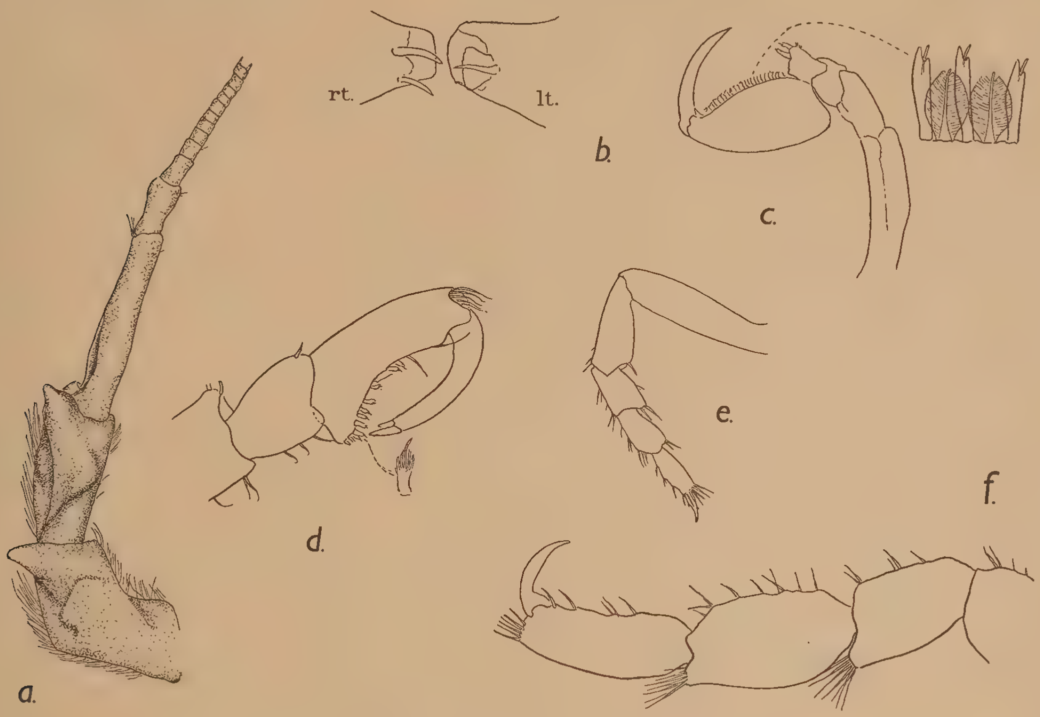

Fig. 20. *Serolis bouvieri*, Richardson.

a, peduncle and ten flagellar joints of antennule: × 20. *b*, cutting edges of mandible: × 15. *c*, second thoracic appendage: × 7. *d*, third thoracic appendage of adult ♂: × 20. *e*, fourth thoracic appendage of ♂: × 6. *f*, last thoracic appendage of ♂: × 20.

The second, third, fourth and eighth thoracic appendages of the male are shown in Figs. 20 *c–f*. The propodus of the second appendage has its inner margin armed with a row of thirty-six broadly oval processes, alternating with peculiar modified spines. The distal edge of the carpus is crenulate and it bears two stout spines, each with a bifid extremity. In the third thoracic appendage of the male (Fig. 20 *d*) the propodus is slightly concave, broader at its proximal than at its distal end; the broad end bears a group of six pairs of stout spines; three or four pairs are arranged along the proximal two-thirds of its surface, and a few simple setae are also present. The spines are of the type shown in the figure. The dactylus is rather short, curved, terminating in two spines, one of which is larger than the other; the inner margins of the carpus and the merus are fringed with numerous fine hairs, which also extend along part of the margin of the ischium. The last thoracic appendage is much smaller than the preceding. In the male (Fig. 20 *f*) the dactylus is short and curved, and the inner margins of the propodus, carpus and merus bear a dense fringe of long delicate hairs; shorter hairs also occur on the outer margins of these joints as well as on the inner margin of the ischium. The setae on the remaining appendages are stout and simple. The entire surfaces of the appendages are covered with minute rounded imbricating scales.

The first three pairs of pleopods are of the type in which the protopodite is triangular, with its produced angle bearing plumose setae—three in the first pair, and two in each of the other two. The suture of the exopod and of the endopod of the fourth pleopod is almost transverse; the outer margin of the former is fringed with plumose setae. The inner distal angle of the protopodite of the uropod is produced and bears strong plumose setae at its tip. The exopod is a little more than half the length of the endopod; both are small and fringed with delicate hairs amongst which, at the distal and outer margins, are strong plumose setae.

DISTRIBUTION. Richardson's specimens were collected at Booth-Wandel Island and the Bay of Flanders; those in the present collection come from the Palmer Archipelago and the South Shetland Islands.

32. **Serolis aspera**, n.sp. (Figs. 21, 22).

Occurrence. St. 39: South Georgia, 179–235 m.; 1 immature specimen.
St. 123: South Georgia, 230–250 m.; 1 immature specimen.
St. 148: South Georgia, 132–148 m.; 3 immature specimens.
St. 160: Shag Rocks, 177 m.; 1 adult ♂, 1 ♀ (b.).

DESCRIPTION. The length of the adult male and female is the same (26 mm.), but the former is slightly broader than the latter and measures 21 mm. in greatest width as compared with 20 mm. The body (Fig. 21) is broadly ovate in shape, with its dorsal surface covered with shallow pits. The colour of spirit specimens is variegated, being partly grey and partly cream: in the adult male, for example, the lateral parts of the cephalosome, the dorsal median spines, the tips and edges of the coxal plates and the posterior part of the terminal segment are all of the lighter colour.

The head is nearly twice as broad as long, broadest anteriorly. The anterior margin shows two shallow excavations, one on either side of the well-developed rostrum; behind the latter is a well-marked transverse ridge which extends across the width of the head. Just in front of and between the eyes is another transverse ridge, the lateral parts of which are higher than the middle. The portion of the head between the eyes is raised into two rounded prominences, the surfaces of which are covered with rounded pits; between these two, posteriorly, is a third small raised area, the centre of which is marked

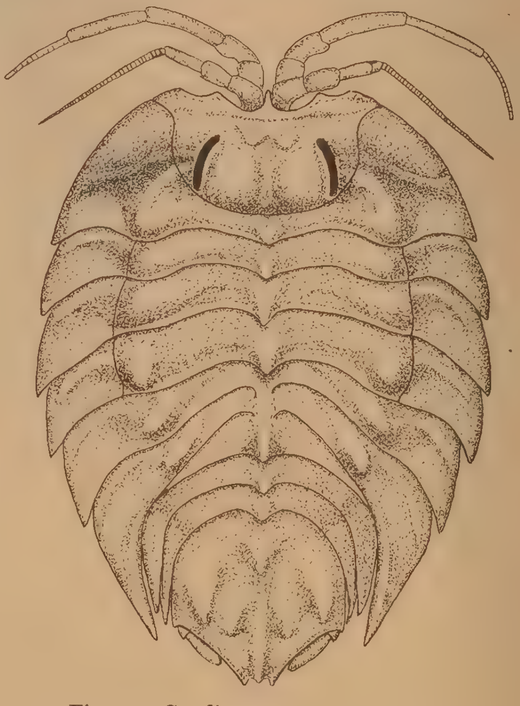
Fig. 21. *Serolis aspera*, n.sp., ♂: × 4.

by a small blunt spine: the posterior margin of these prominences is better defined than the anterior. The eyes (Fig. 21) are about half the length of the head, reniform in shape, rather narrow in proportion to the size of the head, and containing black pigment.

The lateral or coxal portion of the second thoracic somite, which is fused with the head, is divided into an anterior and a posterior portion by a transverse ridge. This ridge commences on either side at a point approximately midway along the length of the eye, and runs at first transversely and then obliquely backwards and outwards, finally disappearing near the lateral margin. The posterior margin of the second thoracic somite is produced backwards as a small median dorsal spiniform process. The third, fourth and fifth thoracic somites are sub-equal; each is produced backwards in the mid-dorsal line into a small spiniform process which increases in length from before backwards. The sixth and seventh thoracic somites are together equal in length to one of the preceding somites; the terga of these two somites are fused with each other and with the tergum of the first abdominal segment for a short distance on either side of the mid-dorsal line. In this character the species agrees with *S. bouvieri*, Richardson, and with the Australian species *S. australiensis*, Beddard, *S. elongata*, Beddard, and *S. longicaudata*, Beddard. In the female the position of the suture between the sixth and seventh somites is indicated by a slight groove.

Well-developed coxal plates are present on each of the third to seventh thoracic somites; these are closely applied together for their whole length in the female, but in the male the tip of each projects slightly beyond that of the preceding one. The coxal plates of the third, fourth and fifth are marked off by distinct sutures from their respective somites; just within these sutures the lateral portion of the somite on each side is raised into a low eminence and similar raised areas are present in corresponding positions on the remaining somites. The coxal plates of the seventh thoracic somite are longer than those of the other segments and, in the male, extend backwards beyond the pleural plates of the second and third abdominal segments to a point level with the distal end of the protopodite of the uropod; in the female they are somewhat shorter and extend to a level equal to that reached by the pleural plates of the third abdominal segment.

The posterior margin of each of the three free abdominal segments is produced into a median dorsal spiniform process similar to those of the thoracic somites; the posterior border of the sternum of each of these segments is produced backwards into a median spine; these increase in size from before backwards, and are considerably larger in the female than in the male. The pleural plates of the third abdominal segment are longer than those of the second and extend backwards to the level of the articulation of the uropod.

The terminal segment (Fig. 21) is broader than long, terminating posteriorly in a slightly up-turned trifid extremity, the middle projection of which is formed by the extension backwards of a low median dorsal keel. Anterior to this keel is a strong median dorsal spine, whilst on either side of it, in a lateral position, is a short ridge ending in a spiniform process at about the level of the articulation of the uropod. Slightly posterior to these ridges, and nearer the median keel, are two small round prominences, one on either side.

The antennule has a four-jointed peduncle: the first joint is broad, geniculated, covered with fine hairs; the second is about the same length as the first, broader distally and covered with dense hairs; the third is nearly one and a half times as long as the second, but narrower, and three times as long as the fourth. The flagellum comprises twenty-five joints in the female, and thirty-seven in the male. The first joint is about equal in length to the fourth peduncular joint; the second to ninth are each about half the length of the first, then gradually increasing in length; the terminal and penultimate joints are narrow, the former bearing two delicate terminal setae. A single sensory seta is found at the distal end of all except the first four joints. The antenna has a five-jointed peduncle. The first joint is short and fringed with delicate setae; the second is a little more than twice as long as the first with longer setae on the inner margin; the third is about equal to the second, broader at the distal end, with a row of five groups of setae on the dorsal surface a little within the margin and a second row of four groups arranged somewhat obliquely. The fourth joint is about twice as long as the third, with six transverse rows each of four groups of setae equidistantly placed, but with the distal row near the distal end of the joint. The surface is covered with short hairs, amongst which longer ones are scattered. The fifth joint is more than twice as long as the third, with five short transverse rows each of four groups of setae. These are near the anterior margin, and arranged more or less equidistantly, the distal row being near the distal end of the joint. The flagellum of the adults of both sexes is incomplete, but in an immature specimen is composed of sixteen joints, of which the terminal and penultimate ones are small.

The mandibles are of the usual type, the form of the right is shown in Fig. 22*a*. The outer lobe of the maxillula bears ten stout spines and one delicate seta on the inner angle of its distal truncate extremity; the inner lobe is about two-thirds the length of the outer, fairly stout, with its oval distal end bearing two minute setae. The maxilla has its two outer lobes each bearing two long setae with a few delicate pectinations along their inner edges; the distal end of the fixed lobe is truncate and bears about ten stout and eight more delicate setae.

The maxilliped is broad, with the basipodite separated from its lamella by a suture; the inner margin of the basipodite is covered with fine dense hairs amongst which are scattered a number of long setae; the second joint of the palp is not much broader at its distal than at its proximal end, and its under surface is covered with scattered setae. The terminal joint is almost parallel-sided, with the rounded distal end fringed with setae.

The second, third, fourth and last thoracic appendages of the adult male are shown in Figs. 22 *b–e*. The propodus of the second is greatly expanded, with its inner margin armed with a row of about thirty-nine broad processes alternating with peculiar modified spines (Fig. 22*b*). The distal end of the carpus is crenulate, and bears two stout spines surrounded by numerous setae. The third thoracic appendage of the male is much smaller than the second, with the propodus expanded and its inner margin armed with a double row of modified spines (Fig. 22 *c*); the inner margins of the carpus, merus and ischium are fringed with a dense mass of short hairs. The last thoracic appendage (Fig. 22 *e*) is smaller than the rest and is similar in the two sexes.

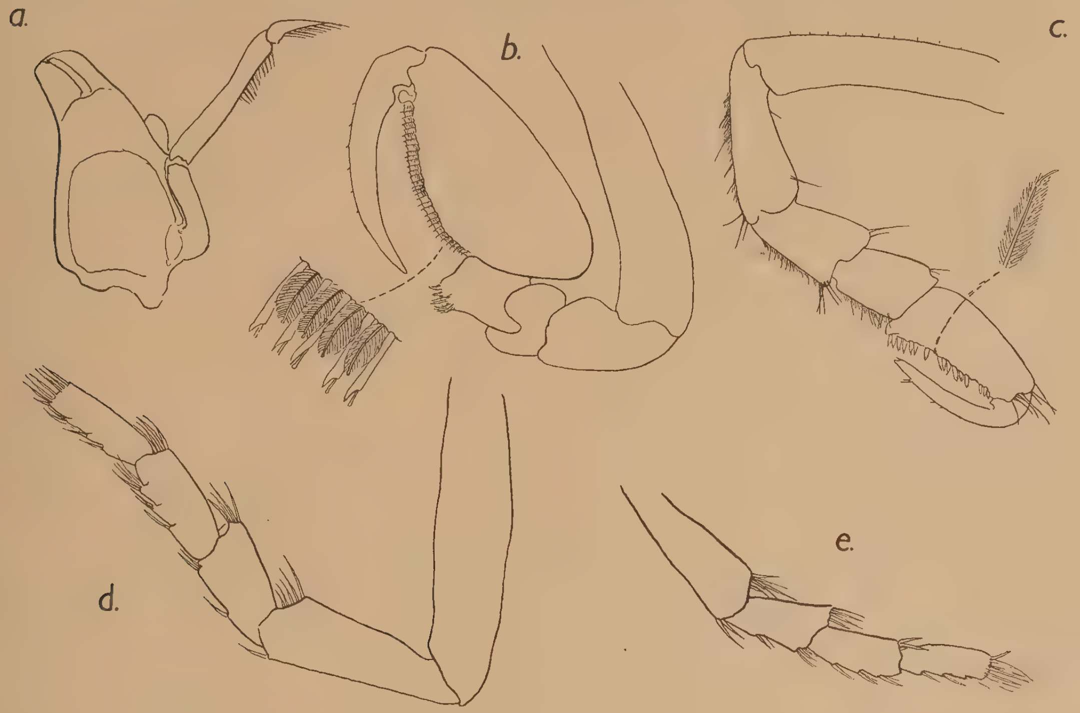

Fig. 22. *Serolis aspera*, n.sp.

a, right mandible: × 14. *b*, second thoracic appendage of ♂: × 14. *c*, third thoracic appendage of adult ♂: × 14. *d*, fourth thoracic appendage: × 14. *e*, last thoracic appendage of ♂, propodus and dactylus missing: × 14.

The protopodite of the first three pairs of pleopods is somewhat triangular in shape, with the produced angle bearing three plumose setae on the first, and two on each of the second and third pleopods. The appendix masculina on the second pleopod of the male reaches about two-thirds of the way towards the apex of the terminal segment. The sutures of the exopod of the fourth and fifth pleopods are almost transverse.

The uropoda do not extend to the tip of the terminal segment; the protopodite has its inner angle produced into a long spinous process and the exopod is about two-thirds the length of the endopod. Plumose setae are present on the outer margin and rounded distal extremity of both the exopod and endopod, and their inner margins are fringed with delicate setae.

Distribution. South Georgia.

This species very closely resembles *S. pagenstecheri*, Pfeffer, but differs from it in the following points:

(1) The most important difference is that in *S. aspera* the terga of the sixth and seventh thoracic somites are fused together and with the first abdominal segment for a short distance on either side of the median dorsal line. In *S. pagenstecheri* the suture between

the sixth and seventh thoracic somites is complete, only the posterior suture of the seventh segment being obsolete for a short distance in the mid-dorsal region; in this species therefore the sixth thoracic somite is free, and the seventh is fused for a short space with the first abdominal segment.

(2) The body of *S. pagenstecheri* is slightly broader in proportion to its length than that of *S. aspera.*

(3) The body of *S. pagenstecheri* is covered with scattered hairs, which are most numerous along the posterior margins of the somites; in *S. aspera* they are very sparse and are not concentrated along the margins of the somites, but are moderately abundant along the posterior free margins of the coxal and pleural plates.

(4) The terminal segment of both species is broader than long, but that of *S. aspera* narrows more rapidly behind the articulation of the uropods; the posterior extremity is definitely trifid in *S. aspera*, in most specimens of *S. pagenstecheri* it is truncate or only slightly trifid.

(5) In both species the terminal segment bears on its dorsal surface a strong median spine in an anterior position, which is followed by a low median carina extending to the posterior extremity of the segment; on either side of this are two lateral carinae ending in spiniform processes at some distance from the lateral margins. In *S. aspera* the carinae next to the median are smaller than the outer, whereas in *S. pagenstecheri* they are all of approximately equal size.

(6) The third joint of the palp of the maxilliped of *S. pagenstecheri* bears at its outer distal angle a minute extra joint which does not extend beyond the end of the third, and bears a group of long setae. This joint is absent from the maxilliped of *S. aspera.*

(7) The thoracic appendages are very much alike in both species; the modified spines on the propodus of both the second and third appendages of the male are similar, and the inner borders of the carpus, merus and ischium are fringed with a dense mass of fine hairs in both species. Similar hairs are present on the propodus, carpus, merus and ischium of the last appendage of the mature male of *S. pagenstecheri*, but these are absent from the corresponding appendage in *S. aspera.*

The distribution of the two species is the same: all recorded specimens have been collected near South Georgia.

33. **Serolis australiensis**, Beddard.

S. australiensis, Beddard, 1884 *b*, p. 69, pl. vi, figs. 3–6; Whitelegge, 1901, p. 237; Chilton, 1917, pp. 396, 400, fig. 10; Nordenstam, 1933, pp. 90–2.

Diagnostic characters. The largest specimen of this species so far collected is a female 14 mm. in length by 11 mm. in breadth, whilst the largest male measures 10 mm. in length and 9 mm. in breadth: as in many Serolids, the males appear to be proportionately broader than the females.

The form of the body is oval; its most characteristic feature is the presence of a large number of tubercles, which are scattered over its surface and are especially large on the posterior borders of the somites and on the dorsal surface of the terminal segment.

The head is broadest at the level of the eyes and ends anteriorly in a very long rostrum; a median spine is present on its posterior border and also on those of the thoracic somites. The central portions of the terga of the sixth and seventh thoracic somites are fused with the tergum of the first abdominal segment, that is, the hindmost sutures of the sixth and seventh somites are obsolete in the middle line. The coxal plates are closely applied together; according to Beddard those of the free somites are all separated by sutures, but I have failed to find more than three pairs of sutures present on the third, fourth and fifth somites respectively.

In the male the coxal plates of the seventh thoracic somite extend for a short distance beyond the extremities of the pleural plates of both second and third abdominal segments, but not as far as the points of attachment of the uropoda; in the female they do not extend beyond the level reached by the pleural plates of the second abdominal segment.

The terminal segment is more or less triangular in shape, with a median keel and a truncate, slightly emarginate extremity. Its dorsal surface is covered with tubercles which are arranged irregularly except for a transverse row which extends across the segment slightly posterior to the articulation of the uropoda: one of these tubercles, close to the lateral margin on either side, is considerably larger than the rest. The exopod of the uropod is shorter than the endopod and its distal end is truncate; the endopod is rounded distally and reaches to the end of the terminal segment.

OCCURRENCE. South Australian coast, 38 fathoms.

34. **Serolis elongata, Beddard.**

S. elongata, Beddard, 1884 *a*, p. 335; 1884 *b*, p. 71; Whitelegge, 1901, p. 236; Chilton, 1917, p. 393.

The original description of this species, which is based on an examination of a single adult female, is extremely brief, and no account of the form of the mouth parts and other appendages is given. More recently the species has been collected on two occasions: it was recorded by Whitelegge in 1901 in his report on the Isopoda of the Thetis Expedition and in 1917 by Chilton, who examined a specimen in the collections made by the F.I.S. 'Endeavour'. Neither of these authors have added anything further to Beddard's description.

DIAGNOSTIC CHARACTERS. The adult female measures 10 mm. in length and 6·5 mm. in greatest breadth. The surface of the body is almost smooth, except that each thoracic somite is furnished with a median dorsal spine on either side of which a row of short tubercles extends along its hinder border and is prolonged on to the coxal plate. The hindmost sutures of the sixth and seventh thoracic somites are obsolete for a short distance on either side of the middle line: I have examined the British Museum specimen and find that the first three free somites are separated from their respective coxal plates by sutures, and also that the coxal plates of the seventh somite extend beyond the pleural plates of the second abdominal but not as far as those of the third. The pleural plates of these segments are short and hardly extend beyond the anterior margin of the terminal segment. The margins of the terminal segment are serrated. A median longitudinal carina is present on the dorsal surface, and on either side of this is a lateral serrated carina; between these and the central carina is "a short ridge running obliquely towards the margin of the caudal shield from a point a little below and to one side of the commencement of the central carina".

OCCURRENCE. Port Jackson, Sydney, 30 fathoms.

35. Serolis longicaudata, Beddard.

S. longicaudata, Beddard, 1884 *a*, p. 336; 1884 *b*, p. 72, pl. vii, figs. 8–10, pl. viii, figs. 1, 2; Whitelegge, 1901, p. 237; Chilton, 1917, pp, 397, 400, fig. 11; Nordenstam, 1933, pp. 92–3.

DIAGNOSTIC CHARACTERS. The only specimen in the Challenger collection is an immature female 7 mm. in length and 5 mm. in breadth; the two specimens described by Chilton are both males, 8 mm. in length and 5 mm. in breadth. The head is broad and terminates in a comparatively long rostrum. The body, excluding the terminal segment, is circular in outline, and the terminal segment projects back for some considerable distance and is proportionately longer than in any other species. The first three free thoracic somites are separated from their respective coxal plates by sutures; the coxal plates are all short and truncate at their distal extremities. Beddard states (1884 *b*, p. 73) that "the tergum of the sixth segment is entirely absent"; this, however, is not the case, but the tergum of both the sixth and seventh somites is very narrow, and the hindmost sutures of both are obsolete for some distance on either side of the middle line, so that the middle portions of these somites and that of the first abdominal segment are fused together. A similar condition is seen in *S. australiensis*, Beddard, *S. elongata*, Beddard, *S. bouvieri*, Richardson, and *S. aspera*, n.sp.

The pleural plates of the second and third abdominal segments are also truncate and do not extend beyond the anterior margin of the terminal segment; the latter is roughly pentagonal in outline, terminates posteriorly in a truncated extremity which is slightly concave, and bears a median and two lateral carinae on its dorsal surface.

OCCURRENCE. Off St Francis Island, South Australia, 6–13 fathoms.

36. Serolis tuberculata, Grube.

S. tuberculata, Grube, 1875, p. 227; Beddard, 1884 *b*, p. 67, pl. vi, figs. 1, 2; Whitelegge, 1901, p. 236; Chilton, 1917, pp. 392, 394, text-figs. 1–9.

DIAGNOSTIC CHARACTERS. The largest recorded specimen of this species is a female measuring 19 mm. in length and 17 mm. in breadth; the measurements given for the male are 12 mm. in length and about the same in breadth, so that, as is usually the case, the male is proportionately broader than the female.

As Chilton (1917, p. 394) points out this species is readily distinguished from other Australian species by "the series of pointed tubercles along the posterior margins of the anterior segments of the peraeon, and by the median tubercles on all the segments". The tubercles are most numerous on the fifth segment, where there may be as many as nine on either side of the median one. The tergal portion of the sixth thoracic somite is very narrow, whilst the middle portion of the seventh somite has disappeared; the first three free thoracic somites are separated from their respective coxal plates by sutures, a fact which is not mentioned by either Beddard or Chilton, neither does the latter show them in his figure of the entire animal: nevertheless they are quite distinct in the specimens at the British Museum.

The coxal plates of the seventh thoracic somite extend backwards to just beyond the base of the uropoda. The pleural plates of the second and third abdominal segments project only slightly beyond the anterior margin of the terminal segment. The latter is broader than long, its broadest part being at the base of the uropoda, from which point it narrows rapidly posteriorly and terminates in a truncate extremity: it bears, on its dorsal surface, a longitudinal median carina on either side of which is a lateral submarginal ridge which extends to just beyond the base of the uropoda, at which point the two are united by a transverse curved ridge.

Occurrence. Bass Strait, Gulf St Vincent, and St Francis Island, South Australia.

37. **Serolis pallida, Beddard.**

S. pallida, Beddard, 1884 *a*, p. 335; 1884 *b*, p. 74, pl. vii, fig. 1, pl. viii, figs. 6–16; Whitelegge, 1901, p. 236.

Diagnostic characters. This species is described by Beddard from two specimens, a male and a female; the latter is the larger and measures 16 mm. in length and 13 mm. in breadth.

The body is oval, smooth, and of a pale brown colour. The head is almost triangular with the apex directed backwards; a long, slender rostrum is present and the eyes are small. The antennules and antennae are of approximately equal length; the first peduncular joint of the former bears three strong tubercles on its upper surface and a tubercle with its apex directed backwards is present on the posterior border of the second joint; the filament consists of twenty-four joints each of which bears two sensory hairs. The fifth peduncular joint of the antenna is much enlarged; the filament is short, consisting of only nine joints. The tergum of each of the third, fourth and fifth thoracic somites is produced in the mid-dorsal line to form a backwardly directed spine; similar, though smaller spines also occur on the abdominal segments. The tergum of the sixth thoracic somite is very narrow, whilst the middle portion of the seventh has disappeared. The coxal plates are short and closely applied together. The terminal segment of the body is roughly hexagonal in outline with a median dorsal keel; its posterior extremity is notched.

After examining Beddard's specimens at the British Museum, I can only add to his description that the first three free thoracic somites have their coxal plates marked off from the terga by distinct sutures, and that the pleural plates of the abdominal segments are short and only extend for a short distance beyond the anterior margin of the terminal segment; the coxal plates of the seventh thoracic somite extend posteriorly for a short distance beyond the pleural plates.

Occurrence. Off Port Jackson, Sydney, 30–35 fathoms.

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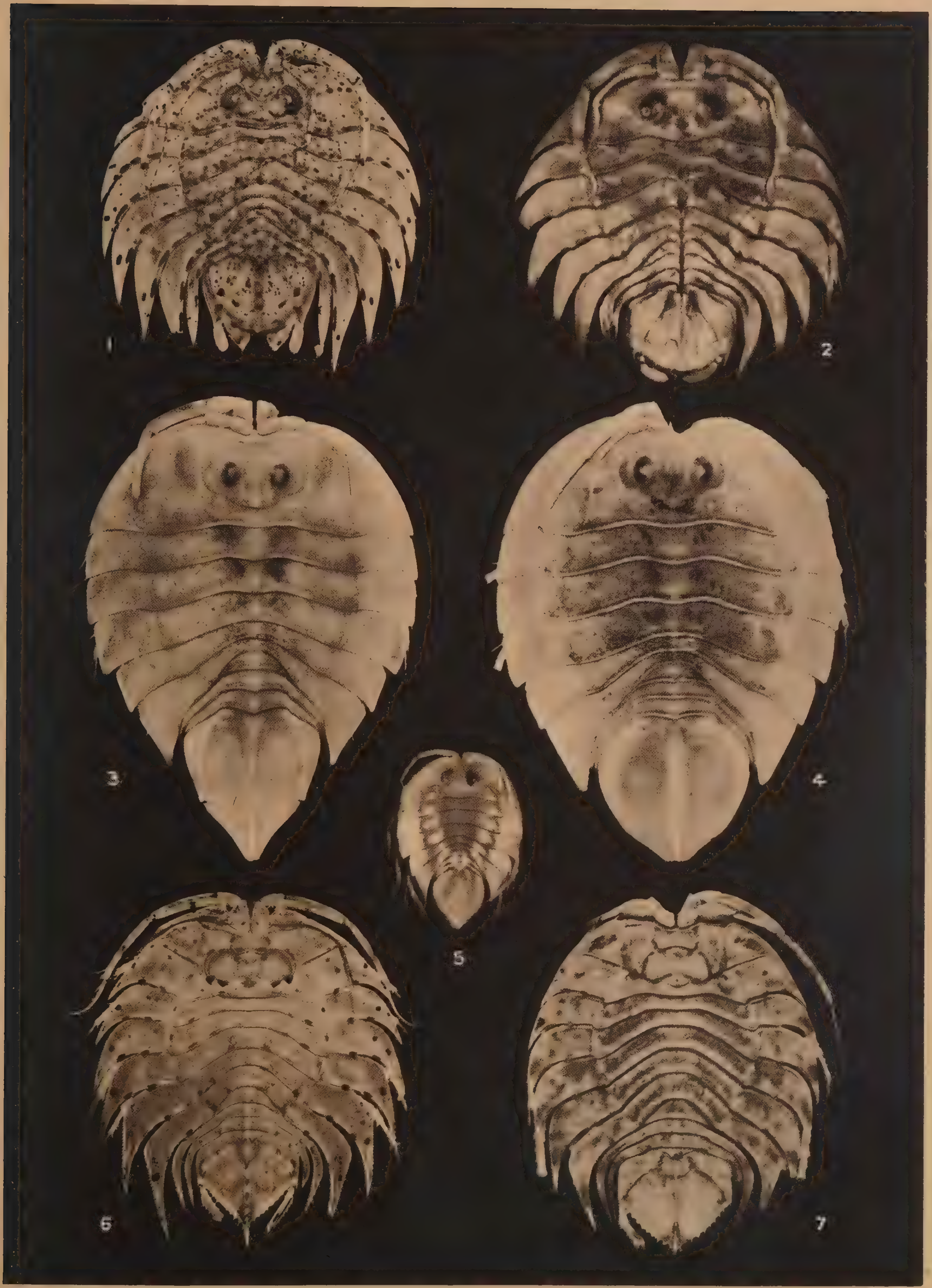
PLATE XIV.

Fig. 1. *Serolis schythei*, Lütken, ♂: × 2.
Fig. 2. *Serolis polaris*, Richardson, ♂: × 3.
Fig. 3. *Serolis convexa*, Cunningham, ♀: × 3.
Fig. 4. *Serolis gaudichaudii*, Aud. et Edw., ♀: × 4.
Fig. 5. *Serolis laevis*, Richardson, ♂: × 2.
Fig. 6. *Serolis cornuta*, Studer, × 1.
Fig. 7. *Serolis trilobitoides*, Eights, × $1\frac{1}{8}$.



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SEROLIS

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SOME ASPECTS OF RESPIRATION IN BLUE AND FIN WHALES

By

ALEC H. LAURIE, M.A.

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SOME ASPECTS OF RESPIRATION IN BLUE AND FIN WHALES

By Alec H. Laurie, M.A.

(Plate XV; text-figs. 1–4)

INTRODUCTION

The investigations which form the subject of this report were performed in two parts. Preliminary examination of the general physiological background of cetacean life was made at the Marine Biological Station in South Georgia in 1930–1. Part of the ensuing year was spent in studying problems of respiration and gaining experience in the technique of blood gas work at Cambridge under the guidance of Professor Barcroft, to whom I am much indebted for advice and laboratory facilities. Field work was resumed in the season 1932–3, when The Southern Whaling and Sealing Company very kindly placed a laboratory at my disposal on board the pelagic whaler 'Southern Princess'. The freshness of whales brought in to a pelagic whaler outweighs the inconveniences of a floating laboratory, since it is important to examine post-mortem material with a minimum of delay.

Some qualification is necessary for the title of this paper. The physiological properties of living southern Blue and Fin whales will in all probability never be known by direct observation, though the smaller whales and porpoises might conceivably be confined and observed. An attempt has been made in the present work to examine the properties of fresh carcasses of Blue and Fin whales from which tentative deductions as to their mode of life have been made. It is felt that such an investigation, which would be superfluous with smaller land mammals, has its justification in that it may help to throw light on the life of one of the world's most inaccessible creatures.

At the suggestion of Professor Barcroft the manuscript of this paper was submitted to Professor August Krogh of Copenhagen. Professor Krogh is renowned for his researches into problems of respiration and blood gases, and I am very grateful to him for a number of criticisms which I have incorporated in the text.

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SOUTHERN WHALES AND THEIR ENVIRONMENT

It will be convenient to review briefly the external conditions of a Blue or Fin whale's life, and later to see how much of its mode of living can be deduced from the application of physiological principles. Blue and Fin whales are very large, entirely aquatic mammals, preferring for the most part to live on the high seas and seldom venturing into shoal water. More than half the year is spent in Antarctic waters, where the temperature of the surface water is rarely more than 4° C. and is frequently below zero. The rest of the year is spent in tropical waters, whose temperature may be as high as 29° C. The whale's only external protection against cold is the blubber, which is generally believed to be thickest at the time of migration from the Antarctic to the tropics and thinnest on the return migration. Since whales cannot regulate their temperature by the use of sweat glands, it follows that they must be able to modify body temperature greatly by variation of blood supply to the skin, if not by control of basal metabolism.

Temperature. Some effort was made in South Georgia to determine the normal temperature maintained in Blue and Fin whales. The procedure was to insert a thermometer into the longissimus dorsi muscle as near as possible to the vertebral column. This was done while whales were being dismembered at the whaling station. It was found that fresh carcasses cooled little before dismemberment and that a slight but irregular rise in temperature was observed when decay commenced. The average temperature of thirty fresh whales was 35·1° C. High temperatures are found near the abdomen, due doubtless to the presence of decaying matter in the stomach and intestinal tract. Morimoto, Takata, and Sudzuki (1921) quote a body temperature of 36·6–36·9° C. from the early work on northern Balaenopterids, but no mention is made of the part of the body in which the temperature was taken. Both these and the South Georgia temperatures suggest strongly that the whale's temperature is lower than that of most mammals. Smith (1895) quotes observations by Seidangrotsky on domestic mammals:

Horse	38·00–38·20° C.
Cattle	38·76–38·96° C.
Swine	39·44° C. average
Sheep	39·72–40·22° C.

Basal metabolism. The problem of temperature maintenance and control leads to a consideration of the minimum energy requirements of a whale which would be sufficient to keep the animal alive in a state of rest (basal metabolism). In this respect, as in others, it will be necessary to make constant comparisons with man's physiological properties, partly because human physiology is better known than that of other land mammals, and partly because man in his submarine ventures has attempted to adapt himself by mechanical means to the conditions under which the whale lives.

One general feature of basal metabolism according to Starling may be applied to whales: "We may say that a warm-blooded animal requires a daily expenditure of about 1000 calories per square metre of body surface to carry out such motor processes as are essential to life" (p. 510). This figure of basal metabolism can be taken as a mammalian constant irrespective of the natural or acquired integument of the animal; presumably each animal has taken steps according to its environment to provide itself with adequate insulation, such as blubber, fur, feathers, and so forth. Basal metabolism is greater in small animals than in large ones, since in small animals the surface area is greater in proportion to body weight; conversely the basal metabolism of a whale may be expected to be small. There is no convenient method of measuring the surface of a whale, though various formulae have been suggested for calculating the area. For the present purpose it will be sufficient to take the Blue whale as representing two cones joined together by their bases, as Guldberg (1907) suggested. The base of each cone may be taken to be a transverse section of the body at the occipital condyles.

A female Blue whale was measured and weighed by Capt. Th. Sørlle at Stromness, South Georgia, in 1926: the length was 27·18 m. (see Appendix, p. 404). The approximate area of the whole whale, calculated as above, was 275 sq. m.; the basal metabolism therefore would be 275,000 calories per day. The weight of this whale was approximately 122,000 kg. The calories per kg. per day necessary to support life would be 2·25. For comparison the following figures are shown (Starling):

	Weight (kg.)	Calories per kg. per day
Man	70	32·9
Rabbit	2·05	58·5
Guinea-pig	0·67	223·1

It would seem therefore that the Blue whale, of which this specimen is fairly typical, has a very small basal metabolism in comparison with smaller mammals. A man of 70 kg. at rest absorbs about 300 cc. oxygen per minute on behalf of his basal metabolism, that is to say 4·28 cc. oxygen per kg. of body weight per minute. The Blue whale's basal metabolism is 14·6 times less than man's, so that the whale's oxygen requirements will be only 0·293 cc. per minute per kg. This whale, then, required 35·75 l. per minute of oxygen, which is contained in 178·75 l. of air.

Vital capacity. Direct measurement of a Blue whale's vital capacity, or the greatest amount of air which can be taken in after the most forcible expiration, is impracticable. The weight of the lungs of the whale under consideration was 1226 kg., 1·24 per cent of the weight of the soft parts, whereas human lungs average 2·37 per cent. Another Blue whale measured and weighed at the same whaling station in 1924 was 20·3 m. long and weighed 48,903 kg. (see Appendix, p. 403). The lungs weighed 1·53 per cent of the soft parts.

If for the moment it is assumed that the lung's capacity is proportional to its weight in whales and human beings, two facts emerge: (1) the whale's vital capacity is approximately half that of man in proportion to its weight; (2) if the human vital capacity is 3·50 l. for a man weighing 70 kg. (Starling), then the vital capacity of the whale first mentioned would be 3050 l. (3·05 c.m.). The minimum air requirements of the whale were estimated above to be 178·75 l. of air per minute. At this rate the whale can stay submerged for 17 min., assuming that all the oxygen in the lungs is used and that no muscular exertion is taking place. The calculation, for lack of first-hand data, has been based on the assumption that the capacity of the lung is a function of its weight. No account so far has been taken of the possibility of a much greater elasticity in whales' lungs than in those of man. Unfortunately no figures are available to show the maximum internal volume of the thorax in the particular whale under consideration, but in a Fin whale measured by myself in South Georgia, length 22 m., the volume of the thorax was 8 c.m. after death, when probably it was not fully expanded. Of this the heart and blood vessels occupied approximately 0·5 c.m., so that there were at least 7·5 c.m. of space available for the accommodation of the lungs. If the vital capacity is taken to be 7 c.m., the whale could remain submerged for 39 min. It would be unprofitable to try to assess more accurately the probable vital capacity of the Blue whale originally considered; but these figures indicate that a submersion period of 17–30 min. for a whale at rest is a very conservative estimate.

DIVING

Depth and duration. What the energy requirements of an active whale would be while submerged it is hard to say. But there is reason to suppose that during long submergence whales do not move rapidly since they frequently reappear after a quarter of an hour close to the spot at which they dived. Little reliable information is available on the normal period of diving of Blue whales. Most observations have been taken when the whale either is being chased or has already been harpooned. A whale tends to hide beneath the surface when chased and the time of submergence is 10 min. or more. A harpooned whale will stay down as long as 25 min., returning to the surface with a rush, and will not again remain submerged for a long period until it has had an opportunity to ventilate the lungs thoroughly. I have noticed that estimates of the time of submergence of whales during the chase are liable to be faulty and greatly exaggerated owing to the suspense which prevails. I have gathered from conversations with Norwegian gunners that the average time of submergence of a Blue whale which is not alarmed is about 10 min. On being chased or harpooned the dive may last as long as half an hour.

The depth to which whales dive is a matter of the greatest interest physiologically, since the pressure on the animal becomes of significance in all considerations of the whale's respiration. The external hydrostatic pressure becomes communicated to the lungs and the air in them, so that pressure affects the most vital processes. There have been many wild estimates of the depth to which whales can dive; but W. Scoresby jun. (1820) has given a conservative account of the behaviour of the Greenland Right whale. "When fish have been struck by myself, I have on different occasions estimated their rate of descent. For the first 300 fathoms the average velocity was usually after the rate of 8 to 10 miles per hour. In one instance the third line of 120 fathoms was run out in 61 sec., that is at the rate of $8\frac{1}{6}$ English miles or $7\frac{1}{8}$ nautical miles per hour....The average stay under water of a wounded whale, which descends steadily when struck, according to the most usual conduct of the animal is about 30 min. But in shallow water, I have been informed, it has sometimes been known to remain an hour and a half at the bottom after being struck and yet has returned to the surface alive....The remarkable exhaustion observed on the first appearance of a wounded whale at the surface after a descent of 700 or 800 fathoms perpendicular does not depend on the nature of the wound it has received,...but is the effect of the almost incredible pressure to which the animal must have been subjected."

Roy Chapman Andrews (1916) records being told that a Blue whale dived straight down, taking one-quarter of a mile of rope (220 fathoms), and remained below 32 min. A Southern Blue whale sometimes takes out 300 fathoms of rope in a steep or nearly vertical dive.

So much for diving under stimulus. Very little is known about the depth to which whales normally dive. Racovitza (1903) estimated 100 m. as the normal maximum. It has been found in the course of plankton investigations in Antarctic waters that whales' food, *Euphausia superba*, occurs anywhere between the surface and 200 m. or so, and that large swarms, such as would concern the whale more than stray individuals, are found either at the surface or anywhere between the surface and 100 m. This suggests that the lower limit of a Blue whale's normal activities in the vertical plane may be 100 m.

A case was related to me in 1931 of a dead Sperm whale which was found off the Peruvian coast entangled in a submarine cable which had broken at a depth of 500 fathoms. The mate of the cable ship 'All America' informed me that when the cable was hauled to the surface it was caught in the angle of the whale's jaws and a loop was twisted round the tail. From these observations it is probable that the whale became entangled in the cable while actively engaged, possibly in pursuit of a cephalopod. The evidence available thus goes to show that whales of various species are able to sustain hydrostatic pressure up to 10 atmospheres in normal life and even greater pressures under provocation. It should, however, be borne in mind that Sperm and Right whales may differ widely in their diving capabilities from Balaenopterids.

BREATH RETENTION. It will be appropriate at this point to consider what may be expected to be the effects of the whale's habit of life on the respiratory system. In the first place a whale must hold its breath. Instead of enjoying a continuous ventilation of the lungs, as do land mammals, the whale has to depend on an intermittent filling and emptying of the lungs which occurs once in 10 or 15 min. (A land mammal, of which in this paper man has been taken as an example, is quite unable to hold the breath for more than 1 min., though longer periods may be endured after training [Starling].) The natural consequences of this compulsory holding of the breath are a tendency to shortage of oxygen and accumulation of carbon dioxide.

It may reasonably be expected that a whale will return to the surface to breathe when actuated to do so by some mechanism analogous to the respiratory centre in man. The system of ventilation in human beings does not provide for a complete change of air at every breath. Only a part of the air in the alveoli, or ultimate subdivisions of the bronchioles, is changed at each breath, so that continuous breathing is necessary. The whale, on the other hand, takes only one breath and disappears below the surface again. It would thus be to the whale's advantage to effect as complete a change of air in the lungs as possible at each opportunity, to get rid of all the carbon dioxide excreted from the blood and take in air containing its full complement of oxygen.

The histological structure of the whale's lungs has been examined in search of any adaptations to the whale's peculiar mode of life. Photomicrographs of distal portions of lungs stained to show elastic tissue and cartilage are shown in Plate XV. Lungs of two species of southern whale are shown: Humpback and Fin whale, each magnified 540 times. The main features of these lung sections are the great thickness of the walls of the infundibula and alveoli compared to those of a man or pig, and the presence of thick bands of elastic tissue surrounding each infundibulum. The epithelial cells of the infundibula seem to be embedded in a mass of spongy material. The Fin whale lung (Pl. XV, fig. 2) is quite collapsed, so that many infundibula are almost invisible. The Humpback lung (Pl. XV, fig. 1) was full of water some time before the dissection was begun, and this may account for the smaller degree of collapse which seems to have occurred. The presence of such large amounts of elastic tissue in the infundibula probably enables the lung to collapse readily and completely when the whale expires, so that the only air left in the lungs is that in the "dead space", or non-flexible portions of the lungs, such as the trachea and bronchi.

INSPIRATION AND EXPIRATION. There is further reason to suppose that the whale makes a more complete change of air in the lungs on each occasion than any other mammal. The blast of expiration, which in the Antarctic is clearly visible as a column of condensing vapour, is usually seen to rise to a height of 20 ft. in half a second; the noise of the expiration is audible on a still day for a distance of at least half a mile. It is obvious that expiration is extremely forcible and that a vast volume of air passes through the blowhole with great velocity.

I have been able to time the acts of expiration and inspiration on occasions when the whale was so close that the movements of the blowhole could be seen. Sometimes it was possible to distinguish the sound of expiration and the more subdued sound of air rushing into the lungs. Otherwise the time of inspiration was taken to be the interval between cessation of the blast and the closing of the blowhole, allowance being made for sound lag due to distance. The total time taken from the commencement of the expiratory blast to the closing of the blowhole preparatory to submersion averages 1·5 sec. Expiration lasts 0·6 sec.; inspiration takes longer, 0·9 sec. Bennett (1931), from personal observation, estimates 2 sec. for the complete act. No attempt seems to be made by the whale to start expiration before the surface of the sea has been broken. A Blue whale may breathe twice in succession with an interval of about 1 min. after a long dive, but normally only one breath is taken at a time.

HYDROSTATIC PRESSURE

As has been indicated above whales are accustomed to undergo considerable pressure in the course of submersion. For every 10 m. depth the pressure is increased by 1 atmosphere, or 14 lb. to the sq. in., so that the absolute pressure bearing on the surface of a whale is 14 lb. per sq. in. plus another 14 lb. per sq. in. for every 10 m. submersion.

A whale at 100 m. is subjected to an absolute pressure of 11 atmospheres (154 lb. per sq. in.). This pressure bears equally on the whole surface of the whale and compresses the internal organs uniformly throughout. It might perhaps be thought that the lungs and heart were immune from compression through the protection of the thorax, but it will readily be seen that if the viscera and musculature with their attendant blood vessels were compressed and the heart, lungs, and great veins not compressed there would immediately be such a surge of blood to the latter organs as would derange all blood-pressure control and engorge them so that life would be endangered. Nor is it to be supposed that the blubber surrounding a Blue whale acts as a rigid or semi-rigid sheath. The blubber, though hard, is flexible and is quite pliable and slack ventrally from the chin to the umbilicus in the region of the ventral grooves. Thus there is less protection afforded by the blubber in the thoracic region than in any other part of the body.

UPTAKE OF OXYGEN. In order to understand fully the implications of hydrostatic pressure on the whale's respiration it is necessary to imagine a whale submerged and staying at a depth of 100 m. for some minutes. Compression of the whole body, including the thorax, results, and with it the air in the lungs also becomes compressed ten times. The effect of this compression on the oxygen uptake will be to raise the partial pressure of the oxygen in the lungs, as pointed out by Ommanney (1932). The partial pressure of oxygen in normal air is about 150 mm. of mercury. A partial pressure of 60 mm. is sufficient to keep the blood of most mammals above 80 per cent saturation with oxygen. The whale's oxygen will be at 1500 mm. of mercury when a depth of 100 m. is first reached and may become ten times as depleted at that depth before inadequate oxygenation of the blood takes place. The oxygen in the lungs would be at a partial pressure of only 6 mm. of mercury when the whale returned to the surface. In other words the whale is able to make the fullest use of the oxygen in the inspired air. There is evidence to show that in animals there is great power of endurance under conditions of progressive anoxaemia. Experiments on dogs (C. W. and C. H. Greene, 1922) show extraordinary endurance, provided the blood pressure and minute volume are maintained.

Ommanney (1932), in discussing this matter, has reached the conclusion that whales do not descend much deeper than 130 ft., but this estimate would appear to be too low even for normal dives, and, though satisfactory evidence is lacking, it appears most probable that when harpooned they can reach still greater depths. Ommanney thinks that whales could not reach a depth of 600 m. because at this depth the hydrostatic pressure, 60 atmospheres, would raise the partial pressure of the oxygen in the lungs to 4 atmospheres and remarks that this has been found by Paul Bert to be toxic in certain animals. Oxygen in the lungs would, however, be toxic at that pressure only if there were an unlimited supply, whereas it will be seen from the figures of blood volume and vital capacity above that one lungful of air (say 7000 l.), containing approximately 1400 l. of oxygen, would serve to supply the blood (8000 l.) with 17 vol. per cent oxygen, which is somewhat below the normal oxygen capacity of human blood but considerably above that of whales, as will be shown later. And, even if it were supposed that a whale dived with its blood fully oxygenated and the lungs full of fresh air, the fluid portion of the whale alone, 60 per cent of the total weight, or 73,200 l., could dissolve 1793 l. of oxygen, or about 25 per cent more than the available volume, if the partial pressure of oxygen were equal to 1 atmosphere. In other words, the volume of oxygen taken down by the whale could be dissolved more than once over in the body fluids before the partial pressure of the oxygen exceeded 1 atmosphere. In any case, as Professor Krogh has pointed out, a large proportion of the oxygen in the lungs would be used up before the whale reached any considerable depth. There is therefore no theoretical obstacle to prevent the Sperm whale mentioned above from reaching the depth of 900 m. at which it became entangled with the submarine cable.

Excretion of carbon dioxide. The accumulation of carbon dioxide in the blood and hence, by diffusion, in the lungs will be considerable. In contrast to the conditions underlying oxygen intake, the heightened pressure is in this case a disadvantage to the whale. The effect of carbon dioxide on the respiratory centre depends on the partial pressure of the gas in the lungs and not on the percentage. A small percentage of excreted carbon dioxide under a high pressure will have the same effect as a large percentage under a low pressure. Accumulation of carbon dioxide is bound to occur, particularly in the blood, and, as will be shown later, considerable volumes of this gas are found dissolved in body fluids as well as in the blood. The conditions which must result from deep diving postulate a less delicate regulatory mechanism for the control of carbon dioxide tension in the blood than exists in man and other land animals. The respiratory centre, if it is similar in action to that of man, must be either adapted to respond to a different range of carbon dioxide tensions or dependent entirely on stimulation by oxygen shortage. One interesting consequence of stimulation by oxygen shortage would be that if the stimulation began at 100 m. the whale's ascent to the surface would cause greater and greater stimulation as the hydrostatic pressure decreased and with it the partial pressure of oxygen in the lungs.

Dissolved nitrogen and caisson sickness. The third consequence of hydrostatic pressure on the whale is the passage of gases from the lungs into solution in the blood and hence into the body generally. The physical solution of oxygen and carbon dioxide in the blood is a minor phenomenon compared with the mechanism for taking these gases into chemical combination. It remains therefore to consider the solution of nitrogen and the inert gases (these latter being of minor importance). The transference of gases from the lungs to the blood follows Dalton's Law of the solubility of gases. Blood dissolves about 1·2 vol. per cent of nitrogen from air at atmospheric pressure. For every atmosphere increase in pressure the blood takes up another 1·2 vol. per cent. This process in human blood is the basis of the trouble known to divers as caisson sickness, in which nitrogen is dissolved in the blood under pressure and on decompression fails to return to the air through the lungs if the diver's return to the surface is too rapid. A summary of a typical case of caisson sickness is here abstracted from Sir Leonard Hill's book on the subject (1912). A petty officer diving at Lamlash in 24½ fathoms of water (= 6 atmospheres) took 40 min. to reach the bottom, remained there 40 min., and took 20 min. to return to the surface. Shortly after coming up he was taken ill and died in 7 minutes. Post-mortem examination showed black or very dark blood in the blood vessels and large bubbles of air in the veins of Galen and the choroid plexus, in the right ventricle of the heart, and in the veins covering the brain. Small vessels of the mesentery attached to the gut were found full of nitrogen. It has been shown that the illness is due to the accumulation of nitrogen in the vessels of the heart, certain blood vessels, and the central nervous system.

In order to see how far caisson sickness may be expected to be a danger to the normal life of a Blue whale it will be convenient to summarize the main features of the illness as it appears in man and other mammals, according to Hill. "The rate at which various animals, and different organs of the same animal, become saturated and desaturated in compressed air is proportional to the volume of blood relative to that of the tissues, and to the velocity of the circulation." The volume of blood in the large Blue whale which was weighed at Stromness in 1924 was 6·6 per cent of the total weight. The blood volume in man is 4·9 per cent of the body weight (Haldane), in the horse 6·6, ox 7·7, sheep 8·01, and pig 4·6 (Ellenburger). No information is available as to the rate of circulation in whales, though it is to be expected that as among land mammals, other things being equal, the rate would be lower in a large animal such as a whale. The low basal metabolism indicated above also suggests sluggish circulation. The heart of the Blue whale according to two observations is about 0·59 per cent of the body weight, the human heart is 0·41 per cent. These figures suggest, but by no means prove, that the whale's heart is not notably larger or more powerful in proportion to the size of the animal than the human heart. "If the activity of the circulation is great enough, the excess of gas may escape by diffusion through the lungs without the formation of bubbles" (Hill). For this reason small animals with rapid circulation are relatively immune from the effects of decompression, while large animals are more liable to the sickness. "When a liquid saturated with gas under pressure is suddenly decompressed the excess of gas does not immediately come out of solution either by bubbles or diffusion. This delay is specially marked in the colloidal body fluids." Hill goes on to say that bubbles are not found in gland cells or muscular fibres (places of rapid circulation of blood) but may, on the other hand, occur abundantly in the collections of body fluids—bile, urine, and synovial and amniotic fluids. Bubbles are found most frequently in the fat, because fat absorbs five times as much nitrogen as water and the circulation through fat is relatively poor. "Oxygen bubbles are not a factor in caisson sickness...." The fat in all cases of decompression is honeycombed like whisked white of egg.

So far the probability that a whale will be liable to caisson sickness seems high. It is hard to imagine that an animal which stayed submerged until the need for fresh air became urgent should come to the surface so gradually as to allow the dissolved gases to diffuse back into the lungs. The time required for desaturation is more than 20 min. per atmosphere in man, so that, on the basis of human performance, if a whale were to dive 100 m. and stay there for 15 min., by which time the supersaturation of the body tissues might be half complete, it would, in order to avoid caisson sickness, have to return slowly to the surface during a period of at least 100 min., which is contrary to observation.

The influence of fatness on the liability to caisson sickness is marked in land mammals because of the high solubility of nitrogen in fat mentioned above. Boycott, Damant and Haldane (1908) have tested guinea-pigs and concluded that fatness increases the susceptibility to death from caisson sickness. The coefficient of solubility of the watery part of the body may be taken to be 0·9 per cent and of the fatty part about 5·0 per cent. Man contains on the average 66 per cent water and 15–20 per cent fat. The fat content of a Blue whale including internal fats varies seasonally but is seldom more than 24 per cent of the weight and frequently as low as 20, so that whales are in proportion little fatter than man.

The Blue whale whose weight has been considered above contained 60·0 per cent water and 22·75 per cent fat. The weight was 122,000 kg. The watery part, 73,200 kg., would dissolve 658·8 l. of nitrogen from air at atmospheric pressure, while the fat, 27,755 kg., would take up 1387·7 l. The total uptake of nitrogen is therefore 2046·5 l. at atmospheric pressure, and in addition the same amount can be absorbed from the air in the lungs for every atmosphere of compression which the whale undergoes. The vital capacity of this whale was estimated conservatively at 3050 l. of air, of which 2440 l. would be nitrogen, so that if the whale stays submerged, even at a depth of 10 m., at which 1 extra atmosphere pressure is applied over and above atmospheric pressure, all the nitrogen in the lungs will eventually disappear into solution in the body fat and fluids. The nitrogen from one breath would obviously be insufficient to overcharge the blood; but the cumulative effect of successive inspirations followed by submersions would be to overcharge the blood, so that in the event of the whale's electing to stay at the surface longer than the instant which is usual caisson sickness might supervene. After a certain number of breaths at the beginning of the whale's life, there would be an equilibrium established between the nitrogen in the blood and the nitrogen in the lungs at the pressure which represented the average depth of submersion. After a time only a little nitrogen would go into solution if the whale dived a little deeper than usual, or only a little gas would come out if the dive were shallower than usual, but there would still be the same danger from decompression bubbles if the whale lingered at or near the surface.

GAS ANALYSES

The theoretical conditions of a whale's respiration construct a scheme of life which condemns the whale never to delay at or near the surface on penalty of caisson sickness. Actually a whale can linger at the surface, as for instance when suckling a calf, and an explanation of this is to be found in the condition of gases in solution in freshly killed whales. It will never be possible to know everything on this subject of whales' respiration for obvious reasons, but, just as the life history of Blue and Fin whales has been reconstructed in considerable detail from examination of their carcasses, so the study of the gas contents of whales' body fluids has thrown light on respiratory activities. It must be clearly realized that this kind of work has limitations and that post-mortem gas analyses may give misleading results. Every precaution was taken to ensure that the specimens used in analysis were as nearly as possible in the condition which prevailed at the moment of the whale's decease. For instance, a sample of blood was never taken from an abdominal blood vessel, where the fermentation of stomach and intestinal contents might have a local effect on the blood gases. Freshness was of course essential; though some specimens were from whales which had been dead 24 hours or more in order to see the effect of staleness and general decomposition on gas values.

TECHNIQUE. A few words should be said about the technique employed. The method of collecting the samples will be described under the appropriate headings. The samples were taken with as little delay as possible from the deck down to the laboratory in the 'tweendecks. Here was installed a gas burette similar to the Van Slyke constant-pressure type (Van Slyke, 1917). This burette was specially constructed by Messrs W. G. Flaig and Sons for use on board ship where the accommodation is limited. In addition to the usual features of a gas burette, there was an extra branch tube at the top for the admission of gases, while below the main tap there were three limbs of large capacity instead of the two tubes in the ordinary model. There was a hole near the top of one of the limbs, which was covered by a strong rubber band. The purpose of this hole was to permit the withdrawal of samples of evacuated fluids from a lower limb through a hypodermic syringe and the injection of small quantities of reagents into the lower half of the burette. Strong spiral springs were fitted to the stopcocks so that the burette could be used for mixing gases with fluids under pressure, and the whole apparatus was constructed of specially hard glass and on generous lines. These modifications were introduced so that the burette might be used as a tonometer and as a Haldane gas analyser as well as in its normal capacity.

The technique of gas analysis of fresh samples was exactly the normal one. Samples were introduced into the burette, which had previously been evacuated and tested, without exposure to air and were evacuated with vigorous shaking. After allowing 10 min. for evacuation, the sample was isolated below the main stopcock while the gases were measured. Carbon dioxide was absorbed by addition of semi-normal caustic soda and oxygen by anthraquinone-beta-sulphonate with sodium hydrosulphite in semi-normal caustic soda. The residual gas in the burette was taken to be nitrogen and inert gases. Some difficulty was at first experienced in bad weather in reading the gas volumes, since the rolling of the ship caused a pulsation of the mercury column. This was overcome by keeping the burette with its rubber tube and levelling bulb all in a fore-and-aft plane and by restricting the surge of the mercury in the tube by a screw clip. Temperatures were taken from a thermometer suspended beside the graduated part of the burette; barometric readings from the ship's barometer. All gas volumes mentioned are corrected to normal temperature and pressure unless otherwise stated. Tests were made to ensure that gases were being fully extracted from liquids by evacuating water which had been allowed to stand in contact with air at various temperatures. The results given by the burette agreed, after correction, with the theoretical values to within 5 per cent. Each sample was re-evacuated after the gases had been measured to ensure that extraction was complete.

The various body fluids will now be dealt with in detail in the following order: urine, allantoic fluid, liquor folliculi, maternal and foetal blood. The gas contents of blubber and connective tissue will also be considered.

URINE

Hill records the accuracy with which the pressure conditions in the lungs of an animal were reflected by the nitrogen content of the urine; advantage was taken of this to find out the degree of supersaturation of urine caused by various pressures in the lungs by drawing the fluid under cover and analysing the dissolved gases. Since the bladder of a Blue whale is nearly always full after death with the walls in a state of tight contraction, against which the sphincters seem able to retain the urine, it was thought that samples of urine from freshly killed whales would be valuable in giving some indication of the gaseous conditions obtaining during the last half hour or so of the whale's life. The bladder is extremely tough and thick, and since there was never gas in the bladder except in one case it is fairly certain that if supersaturation of the urine was found it indicated at least the same amount of supersaturation before death. Supersaturation could not have occurred after death.

The procedure was to puncture the bladder with a sharp knife and quickly immerse a large test-tube in the urine. The tube was immediately closed with a rubber bung while still submerged and promptly placed in a pot of ice-cold water. The last move prevented any tendency to effervescence, in the event of supersaturation, by increasing the solubility of gases in general through lowering the temperature. The tube was then conveyed to the laboratory, and some of the contents drawn from the bottom under paraffin were pipetted into the receiving cup of the gas burette. 0·05 N lactic acid, previously evacuated, was used in the liberation of carbon dioxide.

Several estimations were performed on the same sample of urine. The specific gravity of some specimens was taken, the sodium chloride content by Volhard's method, total carbon dioxide content, and carbon dioxide combined as carbonate and bicarbonate. The dissolved and combined carbon dioxides were differentiated in this way. The total carbon dioxide in the urine was liberated in the burette with the aid of lactic acid. Another portion of the same sample was thoroughly aerated and treated in the burette similarly. Aeration was repeated until a constant minimum carbon dioxide content was found. The difference between the first and second estimations of urine was taken to be the volume of dissolved gas. Professor Krogh has stated that this method of discriminating between free and combined carbon dioxide is approximately valid only when the fluid is fairly acid (pH < 5). It was found, however, that the volume of carbon dioxide which was removed by aeration was exactly equal to the volume which could be liberated by evacuation without reagents. In other words the method was approximately accurate for the measurement of dissolved carbon dioxide.

Table I. *Gas and salt contents of whale urine*

1	2	3	4	5	6	
No.	N_2 in solution vol. %	N_2 capacity vol. %	Total CO_2 vol. %	CO_3 as CO_2 vol. %	NaCl mg./cc.	Remarks
1	0·88	—	9·60	—	—	
2	0·53	—	—	—	—	
3	0·80	—	—	—	—	
4	0·70	—	—	—	—	
5	0·89	—	—	—	—	
6	1·04	—	7·20	—	—	
7	0·94	0·80 (18°)	10·50	—	—	
8	0·53	0·89 (15°)	33·40	3·95	20·60	
9	0·41	0·88 (15°)	40·00	3·90	16·10	
10	0·65	0·83 (15°)	22·00	—	18·70	
11	0·64	—	24·00	—	—	
12	0·88	0·73 (35°)	10·60	3·58	23·36	
13	0·81	—	13·60	—	—	
14	1·14	0·52 (36°)	8·30	1·20	—	
15	0·87	—	29·00	—	21·72	
16	1·06	—	13·20	—	—	
17	1·05	1·09 (12°)	13·80	1·40	23·35	
18	1·71	—	6·30	—	22·78	
19	—	0·81 (18°)	32·80	—	13·57	
20	0·72	0·63 (36°)	35·20	11·50	13·33	
21	1·04	—	10·80	—	26·60	
22	1·26	0·65 (36°)	17·60	—	25·99	
23	0·78	0·60 (36°)	10·80	2·50	23·68	
24	0·92	0·60 (36°)	15·50	0·75	22·80	
25	0·60	—	40·10	—	13·50	
26	0·94	—	10·80	—	22·54	
27	1·39	0·61 (36°)	10·60	2·60	23·35	
28	0·35	—	43·00	—	15·25	
29	0·87	—	14·40	—	26·25	
30	0·85	—	7·40	—	24·30	
31	0·36	—	38·00	—	14·44	
32	0·68	—	26·00	—	21·80	
33	0·91	1·00 (15°)	12·20	—	22·49	
34	0·69	—	13·30	—	18·80	
35	0·36	—	14·00	—	15·78	Some gas in bladder
36	0·79	—	48·00	—	19·70	
37	1·20	—	14·20	—	23·00	
38	0·98	—	21·20	—	22·40	
39	1·53	—	14·80	—	25·80	
40	0·62	0·95 (14°)	35·50	0·73	15·02	
41	0·72	—	13·60	0·17	23·30	S.G. 1·033
42	0·90	—	13·60	0·37	22·95	1·034
43	—	—	22·60	—	9·99	1·029
44	—	—	21·00	0·72	23·00	1·038
45	—	—	15·60	1·20	20·90	1·033
46	—	—	11·00	0·33	22·00	1·034
47	—	—	15·40	—	23·20	1·036
48	—	—	10·80	—	23·20	1·035
49	—	—	11·50	—	24·00	—
50	—	—	22·10	2·10	19·72	1·034
51	—	—	18·60	0·53	21·18	1·034
52	—	—	17·40	—	20·02	1·031
53	—	—	20·10	—	25·65	1·031
54	—	—	11·20	—	25·60	—
55	—	—	7·80	—	24·30	1·037
56	—	—	83·20	42·00	7·10	1·180*

* Protein 30 grm./1000 cc.

In a few cases the solubility of air nitrogen in the urine at atmospheric pressure was estimated at various temperatures. The procedure consisted in shaking the urine in a flask open to the air with a thermometer dipping in the liquid, the whole operation being performed in a water bath. The urine was pipetted off and introduced into the gas burette in the usual way. In order to form a standard of comparison, the technique was as far as possible the same as in treating the sample originally. As will be seen from the figures in column 3, Table I, the solubility of nitrogen in whale urine is low both at 36° C. and at room temperature. Hill quotes two figures for normal nitrogen content in human urine at atmospheric pressure, 1·14 and 0·90 vol. per cent, of which he prefers the latter. The corresponding figure for whale urine is 0·60 vol. per cent. Whale urine contains more salt than human urine, which should not have much effect on the solubility of a gas; but whale urine also contains considerable quantities of protein.[1] Every sample produced a thick precipitate when boiled; a few samples were estimated gravimetrically and an average of 7 g./1000 cc. was obtained. It was apparent from the appearance of many samples which were boiled that the protein content varied considerably, reaching in one case (no. 56) 30 g./1000 cc. The effect of protein would be to reduce the solubility of gases in the liquid, but there may be other reasons for the low figures obtained. The technique of estimating the solubility was the same as that of estimating the original gas content, and the results can therefore be taken to be relative. The conclusion is then that the urine is supersaturated with nitrogen in some cases and not in others, though the balance is in favour of supersaturation of a low order. The average content of forty-one samples was 0·73 vol. per cent, while the solubility was 0·62 at the temperature of the living whale. The issue may have been clouded by the presence of numerous small organisms in the urine, further reference to which will be made in dealing with blood.

The carbon dioxide content of the urine is of interest. In column 4, Table I, some large volumes of total carbon dioxide are recorded in fresh urines; considerable variation is shown, and there is also a variation in the amount of combined carbon dioxide present in those samples which were estimated. Large amounts of combined carbon dioxide are rare and probably have no connection with the balance of respiratory gases. Specimens 20 and 56 had large combined carbon dioxide, especially no. 56, which is an exceptional specimen in several other ways—high specific gravity, very low salinity, and very high protein.

Control experiments were made with human urine, which was treated in exactly the same way. Variable results were obtained from the same subject, and the dissolved carbon dioxide ranged from 1·24 to 5·40 vol. per cent. The combined carbon dioxide was below 1·0 vol. per cent.

In Fig. 1 the volumes of carbon dioxide found in whales' urine have been arranged along a line which represents the solubility graph of water at 36° C. Each volume found is placed on the line opposite the appropriate ordinate so that it is possible to read off on the abscissa the partial pressure of carbon dioxide which is necessary to cause that volume of gas to go into solution. The results of the control experiments are also recorded. By analogy with the behaviour of nitrogen it appears that the gas content of human urine tends to be slightly above that which would be expected from an equilibrium of the carbon dioxide in the alveolar air, standing constantly at 40 mm. of mercury, with the blood and hence with the other body fluids. The average human urine gas content corresponds to a partial pressure of about 60 mm. of mercury in contrast to the 40 mm. which was expected, a state of affairs which might be accounted for by the diffusion direct into the urine of the carbon dioxide generated in the capillaries surrounding the kidney tubules. The main point is that in comparing the carbon dioxide pressures in human and whale urine a variation of 20 mm. either way is of no great significance. It should be mentioned that in those cases where the combined carbon dioxide has not been directly estimated the dissolved carbon dioxide has been computed by subtracting the average combined gas, 2·20 vol. per cent, from the

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[1] A number of specimens were examined under the microscope and found to contain millions of organisms identical in appearance with those referred to in the section on blood. It is possible that these organisms are excreted through the kidneys.

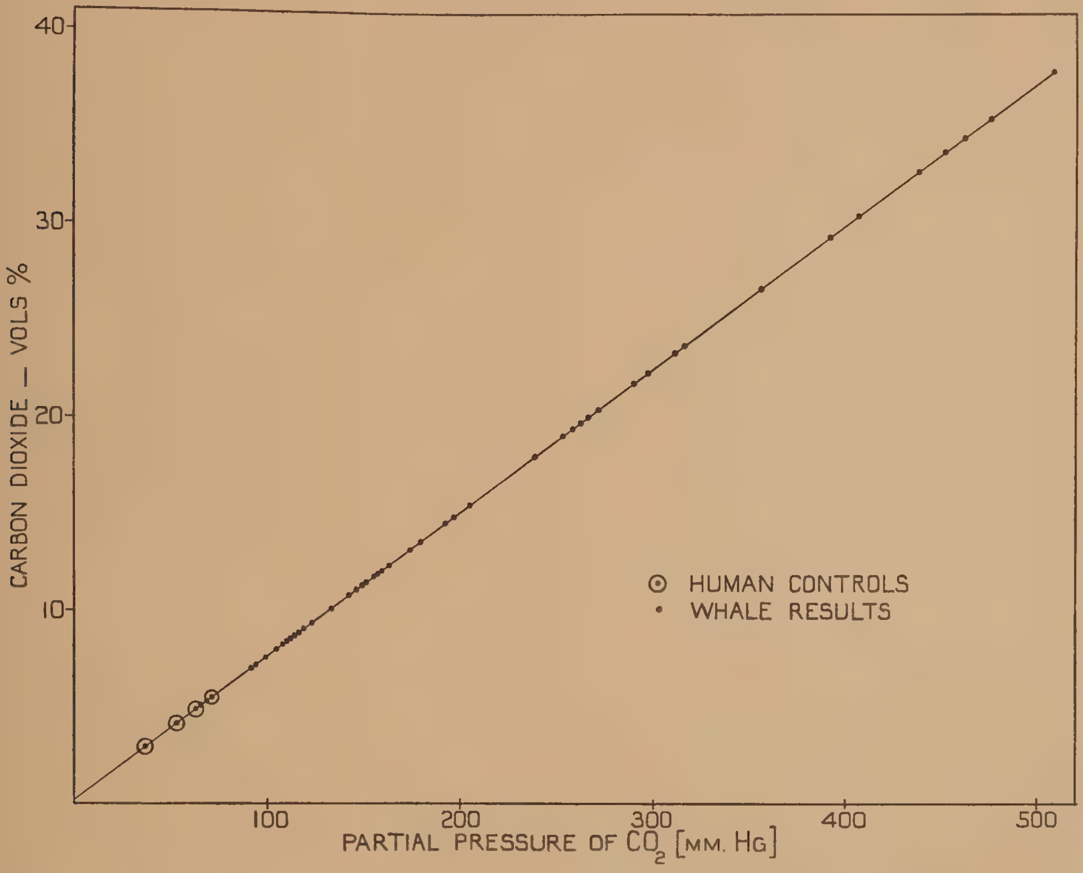

Fig. 1. Carbon dioxide contents of whole urine superimposed on the solubility curve of carbon dioxide in water at 36° C.

total carbon dioxide. This average does not include the combined carbon dioxide in sample 56, which is taken to be exceptional.

The graph shows that twenty-six out of the fifty-six gas contents are grouped round a partial pressure of 140 mm. of mercury, or roughly twice that of the human controls, three agree approximately with human tensions, and the remainder are spread fairly evenly over tensions ranging from 240 to 540 mm. of mercury. It must be remembered that the tensions of carbon dioxide in the lungs which gave rise to these volumes of gas in the urine through the medium of the blood can have originated in one of three ways: by accumulation of carbon dioxide in the lungs during a long dive, or by a compression of the carbon dioxide, or by a combination of the two. It is not therefore possible to judge the depth of diving which caused a given tension of carbon dioxide unless the duration of the dive is also known. But it is perhaps significant that such a large accumulation of gas *per se* would derange the hydrogen-ion concentration of the blood and other fluids, while increased pressure would have the effect of transmitting carbon dioxide through the blood to the urine at high tension, but without seriously altering the reaction of the blood. It is therefore likely that the carbon dioxide tensions implied by the condition of the urine are an indication of the depth to which the whale dived during the last half hour or so of its life. The group mentioned above which centres on 140 mm. of mercury in all probability represents the general state of carbon dioxide conditions in the body, and it suggests a habitual depth of submersion of between 20 and 30 m. The remaining whales showing tensions higher than 140 mm. of mercury are those which dived deep and long in their efforts to escape from the harpoon, while the group of three low tensions is evidence of a small minority which had been basking or feeding at the surface for some hours previous to capture. (A small proportion of whales are killed by the first harpoon without a struggle.)

The interpretation of these figures must be open to suspicion because urine is constantly being generated and excreted and hence reflects only the whale's recent activities. A stationary body of fluid, such as allantoic fluid, which will be considered later, shows with more precision the whale's normal or habitual condition.

The salt contents of these samples of urine, some of which are recorded in column 6, Table I, show considerable variation. That there appears to be some relation between the dissolved carbon dioxide and the salinity of the solvent is shown in Fig. 2, from which it may be concluded that to some extent the salinity is inversely proportional to the volume of dissolved gas. These results may indicate that the presence of carbon dioxide at high pressures in the body of the whale is accompanied by an increased excretion of urine and that this diuresis serves to carry away considerable quantities of carbon dioxide which would otherwise discommode the whale. It is impossible to say whether this diuresis, which can be said to coincide with times of high external pressure, is a direct result of increased difference between the blood pressure in the glomeruli and the pressure in the ureter, giving rise to increased filtration, or whether it is caused by more deliberate control of kidney activity, e.g. by dilatation of kidney blood vessels. It is plain that an aquatic animal has ample opportunity for passing water through the body if need be, though the absorption of water isotonic with the blood from sea water would entail the expenditure of energy. Under the circumstances it is probable that the extra water thus excreted, whatever the reason, is withdrawn from the blood plasma temporarily when the whale is under high pressure, compensation being made from the sea at leisure when severe demands are not being made upon the whale's metabolic resources.

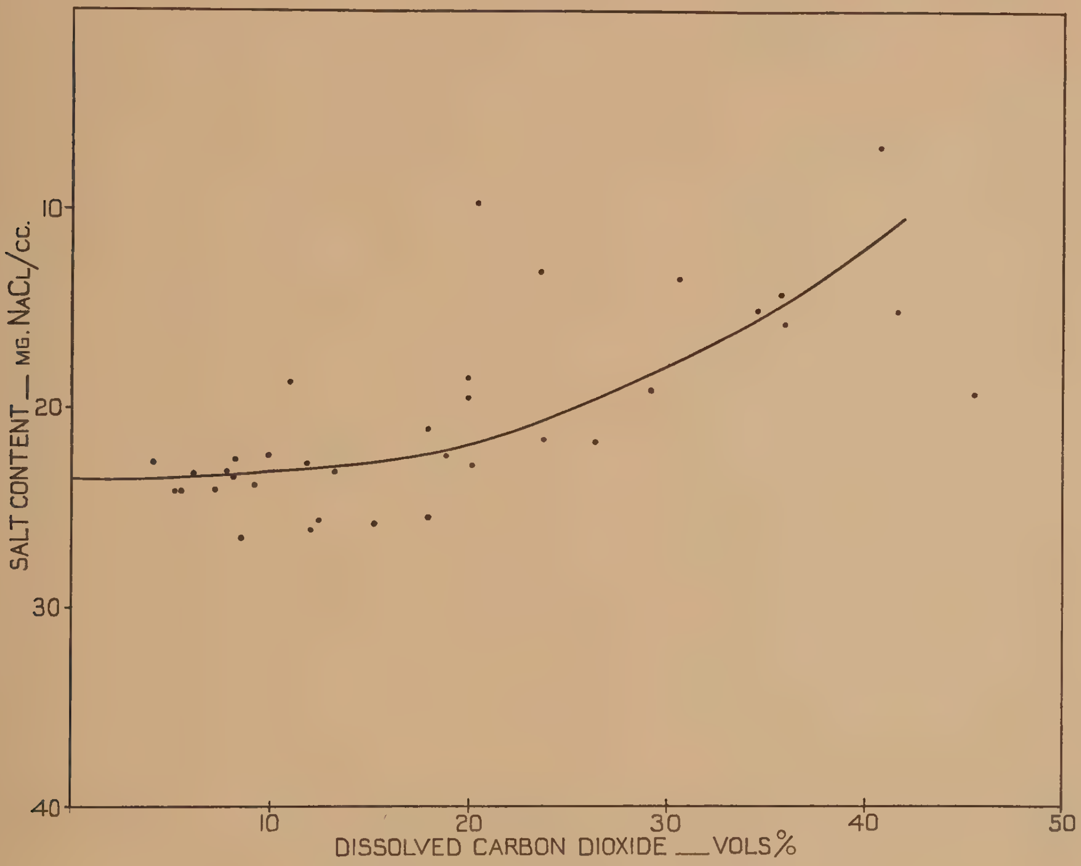

Fig. 2. The relation between the dissolved carbon dioxide and the salt content of whale urine.

Professor Krogh objects to this theory of carbon dioxide excretion on the ground that the quantities thus disposed of would be negligible, since they would correspond at most only to the volume of urine compared with the volume of the whale. It is not known by what means whales are able to avoid taking up salts from their food or from sea water swallowed. It is evident that a mechanism of some sort exists, so that there is no reason why whales should not extract from the sea unlimited quantities of water isotonic with the blood and pass it immediately through the kidneys.

ALLANTOIC FLUID

Table II. *Gas and salt content of allantoic fluid (Blue whales).*

The dissolved CO_2 is obtained by subtracting "CO_3 as CO_2" from "Total CO_2".

No.	N_2 in solution vol. %	N_2 capacity vol. %	Total CO_2 vol. %	CO_3 as CO_2 vol. %	NaCl mg./cc.
1	0·86	0·60 (35°)	19·1	3·5	1·76
2	1·17	—	29·0	11·0	5·70
3	0·78	—	27·5	—	2·16
4	1·67	0·87 (36°)	34·0	11·0	4·15
5	0·78	—	30·1	—	3·15
6	0·69	—	40·0	—	0·81
7	0·55	—	28·6	—	0·94
8	0·87	—	30·5	—	1·16
9	0·79	—	31·0	—	6·34
10	—	—	—	—	1·42
11	—	—	34·1	13·2	Trace
12	1·17	—	31·0	—	3·50
13	1·13	—	36·7	—	2·88
14	0·62	—	75·0	51·0	7·08
15	1·62	—	55·2	33·0	4·05
16	1·07	—	37·8	15·0	1·35
17	—	—	41·0	19·3	1·35
18	—	—	24·6	11·2	1·35
19	—	—	70·6	36·9	2·71
20*	—	—	24·2	17·8	1·61
21	—	—	74·4	44·1	6·93
22	—	—	41·1	—	7·15

* Gas found over fluid in allantois.

The results of analyses of allantoic fluid, performed in exactly the same way as has been described for urine, are shown in Table II. The allantois in Blue whales is a large bag occupying the fork of the division of the umbilical chord, which bifurcates at some distance from the umbilicus—about 2 m. when the foetus is half developed. The urachus runs in the middle of the chord and opens direct into the allantois. The capacity of the allantois increases with the growth of the foetus and contains about 50 l. of fluid when the foetus is half developed.

Slight supersaturation with nitrogen is again apparent. More attention has been paid to carbon dioxide content, which is seen to be high, as in urine. Large amounts of combined carbon dioxide were found in the twelve samples in which this was estimated. The dissolved carbon dioxide, obtained as before by subtracting the combined from the total carbon dioxide, shows less variation than in the urine; the range is from 13·4 to 33·7 vol. per cent, excluding no. 20, in which a large bubble of gas was seen above the liquid before the allantois was punctured. The average content is 22·4 vol. per cent; four samples have contents agreeing with the average to within 1 vol. per cent. These figures for allantoic fluid are considered to represent more nearly the normal conditions of carbon dioxide tension in the whale in contrast to the temporary states reflected in the urine. The average carbon dioxide tension responsible for these contents is about 320 mm. of mercury.

LIQUOR FOLLICULI

One sample only was taken from a ripe ovarian follicle and submitted to the same tests. The total carbon dioxide was 69·6 vol. per cent. The combined carbon dioxide was 45 vol. per cent, so that the dissolved carbon dioxide was 24·6 vol. per cent, a figure which approximates to the average content of allantoic fluid.

BLUBBER

In view of the findings mentioned above (Hill) on the high solubility of nitrogen in fat, special attention was paid to the possibilities of extracting the gases from blubber. The spongy connective tissue between the blubber and the muscles, which is particularly plentiful on the throat and belly of the Blue whale in the region of the ventral grooves, was found to be inflated and in a condition which resembled whipped white of egg. Portions of this material were taken and the gases extracted. It was found that the tissue was inflated with almost pure air. The average percentage of oxygen in five experiments (five different whales) was 21·33 with a range of 21·09–21·60; the remaining 78·67 per cent consisted of nitrogen and inert gases. This is doubtless due to the practice of inflating whales by compressed air after death in order to render them buoyant for towing. The syringe is inserted through the blubber and the air is blown into the space between the blubber and the musculature. There is no evidence that the air has any effect on the gas contents of blood and body fluids except perhaps on the blood in the superficial musculature, since the volumes of oxygen in body fluids have always been found negligible. Occasional deep penetration of the syringe has resulted in an inflation of the abdominal cavity. The percentage of oxygen in the injected air is too high since atmospheric air contains not more than 20·9 per cent. The explanation of this is probably to be found in the great solubility of nitrogen in fat as a result of which more nitrogen than oxygen has dissolved into and diffused away in the blubber before the sample is taken. The gas contents of blubber thus have no significance. The only other convenient source of fat was the peritoneal fat, which is plentiful in whales in good condition. But it was considered dangerous to rely on results from this material, as the proximity of the stomach and its fermenting contents might introduce large errors.

BLOOD

METHOD OF COLLECTION. For reasons which have been mentioned in other sections, it was desirable to draw samples of blood from parts of the body in which one might expect the blood to be as nearly as possible as it was when the whale died. It was therefore decided to take samples from the small arteries which are found in profusion running in the blubber on the top of the head. The head was chosen because it is a large inflexible mass wherein the blood would not be disturbed by the undulations of the body during the towing of the whale to the factory ship, and because it is far distant from both the air blown subcutaneously into the belly region and the fermenting alimentary tract. When the blubber is stripped off the head the blood spurts from these small arteries. In order to collect the blood without exposure to the air, a small glass cannula was inserted into an artery and connected to a large test-tube which contained paraffin oil. The cannula and connecting tubing were filled with oil. The blood then ran through the cannula into the test-tube under the oil until the oil reached the top of the tube. A cork was then inserted, displacing some of the oil and sealing the tube, which was then taken below to the laboratory. Foetal blood was collected by cutting open the thorax and heart in one motion and rapidly submerging a tube in the blood which welled up freely. The cork was inserted under the blood as in collecting urine. On occasions when the blood could not be taken below immediately the tube was immersed in ice cold water.

THE TECHNIQUE OF GAS ANALYSIS. In this series of estimations of the blood gases special attention was paid to the conditions of oxygen and nitrogen. Less attention was given to the carbon dioxide values of fresh blood, for it was found that plain evacuation of a sample of blood did not extract carbon dioxide completely although all the nitrogen and oxygen were extracted. Since the main object was to assess the dissolved nitrogen, no lactic acid was used to expel the carbon dioxide, as the addition of acid might have caused slight flocculation of the protein constituents of the blood to the occlusion of some of the nitrogen. The extraction of oxygen and nitrogen was carried out without reagents. At first gas-free water was used as a diluent to hasten evacuation, but, after some control experiments had shown that extraction of nitrogen was as rapid without the water, the diluent was abandoned to simplify the manipulation. The procedure was to evacuate the blood with frequent shaking for 10 min., isolate the blood in the lower half of the burette, and absorb carbon dioxide and oxygen with the usual reagents.

NITROGEN AND OXYGEN IN FRESH WHALE BLOOD. The nitrogen and oxygen content of samples of blood are shown in Table III. It was impossible to obtain accurate data as to the time that had elapsed from the death of the whale to the drawing of the sample, but in no case had the whale been dead more than 12 hours and the majority less than 6. The only exception is sample no. 99, which was deliberately taken from a decomposing whale. The table shows the results of all the analyses which were performed. The significance of the nitrogen and oxygen contents will be discussed later; for the moment it will be enough to point out that only six samples (nos. 27, 49, 68, 69, 74, 99) show supersaturation to correspond to a pressure of between 2 and 3 atmospheres, while only one of the six (no. 69) indicates a pressure of more than 4 atmospheres in the air nitrogen in the lungs. Thus supersaturation in blood, a viscous colloidal fluid, is more rare than in urine and allantoic fluid.

It will also be seen in Table III that the majority of the blood nitrogen volumes are less than the normal solubility of atmospheric nitrogen in blood at barometric pressure. The average content for the whole series, including the supersaturated samples men-

Table III. *Nitrogen and oxygen contents of arterial whale blood.*

F after the serial number denotes foetal blood. The sample numbers are not consecutive because not all the samples were examined for these gases.

Sample no.	N_2 vol. %	O_2 vol. %	Sample no.	N_2 vol. %	O_2 vol. %
6	1·20	0·96	64	1·00	0·55
10	1·30	0·89	66*F*	0·22	0·00
12	0·53	3·52	67	1·55	0·66
14	1·44	1·40	68	2·95	0·00
15*F*	0·71	0·35	69	5·60	0·00
16	1·18	0·35	70	1·50	0·00
17	1·03	0·45	71	1·70	0·15
18	1·10	0·75	72*F**	1·76	0·54
22	1·78	0·65	73	1·05	0·35
23	0·61	—	74	2·70	0·00
25*F*	0·53	—	75	1·03	0·50
26*F*	0·26	0·82	76*F*	0·40	0·20
27	2·75	0·20	77	0·89	0·89
28*F*	0·33	0·22	78	0·88	0·23
29	0·66	0·33	79	1·01	0·33
30*F*	1·56	1·60	81	0·33	0·33
31	1·10	2·00	82*F*	0·46	0·00
32	1·03	0·99	83*F*	0·30	0·45
33	0·55	0·55	84	1·30	0·23
34	0·77	0·62	85*F**	0·65	0·10
36	1·09	1·31	86	0·77	0·99
37	0·85	0·20	87	1·13	1·13
38	0·63	0·30	88	1·69	0·10
39	0·90	0·80	89	0·89	0·23
40	1·30	0·22	90	0·89	1·10
42	1·04	0·26	91	1·10	0·89
43	1·74	0·17	93	1·08	0·04
44	1·07	0·17	94	0·68	0·22
45	1·11	0·44	95*F*	1·23	0·33
48	1·54	0·66	96	1·34	0·08
49	2·95	0·00	97	1·68	0·00
50	1·06	0·60	98*F*	0·44	0·00
51	0·56	1·46	99†	2·70	0·34
52	0·48	0·56	100	1·12	0·22
54	1·34	0·34	101*F*	0·37	0·00
55	0·82	0·51	102	0·18	0·00
56	0·55	0·22	103	0·66	0·44
57	1·11	—	104	1·56	0·10
58	1·11	0·22	105	1·15	0·25
59	0·73	0·49	106	0·75	0·35
60	1·23	0·45	107	1·06	0·18
61	1·23	0·45	108	0·98	0·34
62	0·72	0·57	110	1·22	0·15
63*F*	0·66	0·66	111	0·92	0·22

* Foetus of preceding whale.

† Stale blood. 5 hours later the inert gas content had increased to 4·60 vol. per cent.

tioned, is 1·116 vol. per cent, or slightly below the human blood figure, which is 1·20 vol. per cent.

Solubility of nitrogen in whale blood. So far comparison has been made between the nitrogen volumes existing in whale's blood and the human solubility coefficient for dissolved atmospheric nitrogen. The peculiar circumstance has been revealed of a mammal having less nitrogen in solution than should have been dissolved normally in accordance with established physical laws, even without high pressures which should cause the solution of even greater volumes of gas. When, however, control experiments were performed to ascertain the solubility of air nitrogen in whale's blood, it was found that more than the expected 1·20 vol. per cent were taken up. These experiments consisted simply of exposing blood samples to air by shaking them in an open flask, both at room temperature and at 36° C. Gas analysis was performed as for the original sample. Variable results were obtained by this method, the full significance of which was not realized until it was found that inevitable delay in manipulation influenced the volume of residual nitrogen. A number of nitrogen "capacities", some of which represent residual nitrogen in estimations of the oxygen capacity of the blood, are shown in Table IV. Reagents used in oxygen estimations were, of course, carefully evacuated and tested before introducing the blood into the burette.

Table IV. *Nitrogen capacity of whale blood from aeration followed by gas analysis.*

Sample no.	N_2 capacity vol. %	Sample no.	N_2 capacity vol. %
3	2·81	27	3·33
5	2·58	29	1·77
6	2·02	30*F*	2·18
7	2·95	33	1·58
8	2·30	35*F*	1·77
9	2·62	37	1·42
10	1·81	38	1·62
11	2·53	40*a*	1·43*
13	1·63	40*b*	3·20
14	1·28	45	1·93
16	1·42	65	2·36
17	2·02	78	1·58
21*F*	1·55	79	1·68
22	2·20	81	1·99
23	2·06	94	1·59
25*F*	2·83		

* 10 minutes' interval between aeration and gas analysis.

It is evident that whale blood is able to take up more than the normal amount of nitrogen from the air. The highest figure found by this method was 3·20 vol. per cent in no. 40. The plasma of no. 7, which sedimented rapidly, was treated in the same way in two separate experiments; the nitrogen capacity was in each case 3·14 vol. per cent. Unfortunately not much attention could be paid to plasma for lack of an effective centrifuge, but the results obtained with this sample indicate that the ability to hold extra nitrogen resides in the plasma and not in the corpuscles, a conclusion which will be substantiated in other ways later.

Another method, in which the progress of nitrogen into solution was directly observed, was used for determining the nitrogen capacity of the blood. The procedure is as follows. A sample of blood whose initial nitrogen content is known is put in the gas burette and a known volume of air is introduced over the blood. The exact volume of air is measured wet as it stands over the blood after the upper stopcock has been sealed with mercury. The burette is now inverted so that the air in the narrow graduated portion is displaced by mercury and forced into contact with the blood in the bulb of the burette. Vigorous shaking of the burette helps the mixing of the blood and air. At intervals, the burette, in which the blood and air have been carefully kept at atmospheric pressure, is restored to the vertical position and the volume of gas standing over the blood is read. Inversion and shaking are repeated between readings, and at each reading a trace of sodium hydroxide solution is run into the burette to absorb the carbon dioxide evolved by the blood. All the oxygen in the air is absorbed in the first two shakings. Before reading the volumes of nitrogen a trace of oxygen absorption mixture is added to ensure absence of oxygen. Protocols of an experiment on these lines are as follows:

Sample no. 100: nitrogen content 1·12 vol. per cent; uncorrected volume 1·25 vol. per cent.
10 cc. of this blood enclosed in burette with 0·945 cc. of air measured wet at 15° C.

Initial nitrogen in the air			0·747 cc.
After	5 min.	oxygen + nitrogen	0·760 ,,
,,	10 ,,	nitrogen	0·710 ,,
,,	20 ,,	,,	0·650 ,,
,,	25 ,,	,,	0·640 ,,
,,	30 ,,	,,	0·620 ,,
,,	35 ,,	,,	0·610 ,,
,,	40 ,,	,,	0·610 ,,

At the end of 35 min. the blood had absorbed 0·747 – 0·610 cc. = 0·137 cc. = 1·37 vol. per cent at room temperature and pressure.
So that the nitrogen in the blood was then 1·25 + 1·37 = 2·62 vol. per cent.

The results of this experiment and others are shown graphically in Fig. 3, where the volume of nitrogen absorbed in addition to the volume already in solution have been plotted against time. It is of course to be realized that the means used for mixing the blood and air were inefficient, and that under ideal conditions of mixing the absorption of nitrogen would in all probability proceed much faster.

While different samples of blood give different nitrogen capacities, the nitrogen capacity of any one sample is fairly constant. For example, the nitrogen capacity of no. 108 was estimated four times: (1) starting from the initial nitrogen content of 1·08 vol. per cent (uncorrected), (2) after evacuation, (3) after a second evacuation and treatment with pure nitrogen instead of air, (4) after removal of nitrogen after (3) by a third evacuation. The nitrogen capacities were respectively 2·32, 2·34, 2·66, and 2·36. The higher capacity in (3) is the result of using pure nitrogen, and the difference between it and the other capacities is approximately the volume of extra nitrogen which would go into solution in water when the partial pressure of the gas was 760 instead of

608 mm. of mercury as in air. Octylic alcohol, which is commonly used in gas analysis to prevent frothing, tends to diminish the nitrogen capacity. Fortunately whale blood seldom froths or these experiments would have been impossible. During one of these experiments, on sample 101, it became difficult to make a direct reading of the volume of gas overlaying the blood, and a trace of octylic alcohol was added with the sodium

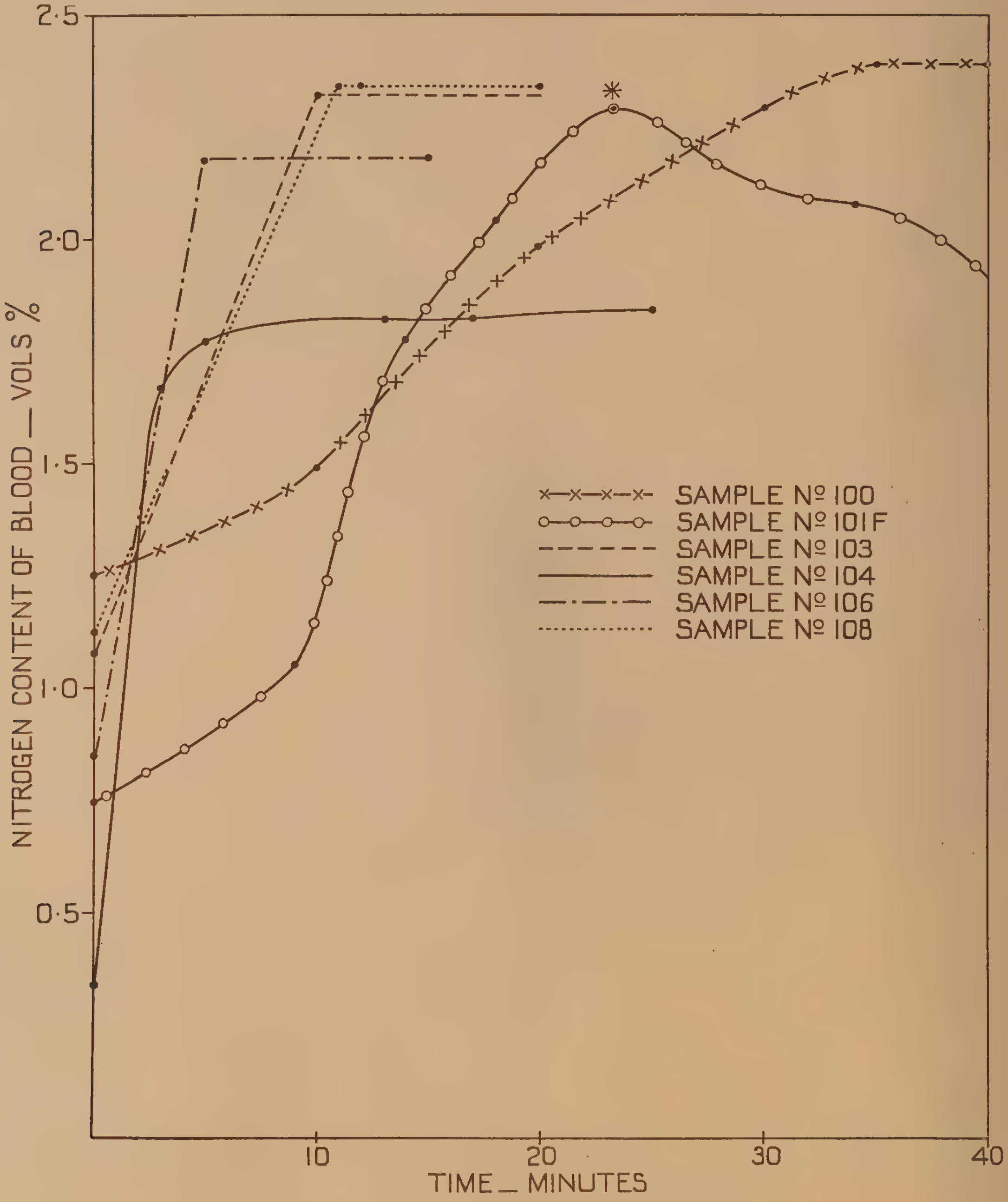

Fig. 3. Progressive solution of nitrogen in whale blood.
* Octylic alcohol was added at this point and nitrogen came out of solution again.

hydroxide. Immediately the absorption of nitrogen was reversed as is shown in the graph. Octylic alcohol was added at 23 min. after the commencement of the experiment. The nitrogen content of this sample dropped from 2·29 to 1·40 at the end of 1 hr. and 20 min., a figure little above the solubility of nitrogen in other types of mammalian blood. Subsequently it was found that whale blood would never take up nitrogen to its full capacity when there was contamination with octylic alcohol. This effect was not observed in control experiments on the solubility of nitrogen in fresh pig's blood with and without octylic alcohol, wherein the solubility was 1·11 vol. per cent at 36° C.

It now appears in the face of these nitrogen "capacities" that the samples of whale blood, whose average content was 1·11 vol. per cent, instead of being merely not supersaturated by comparison with the normal nitrogen solubility of blood are in fact all "sub-saturated" by comparison with their own capacity for nitrogen. Such a state of affairs is plainly at variance with the known application of Dalton's Law on the solubility of gases. It can only be explained by postulating either a state of negative gas pressure in the lungs of living whales, which is unthinkable, or a mechanism for disposing of dissolved nitrogen from the blood.

DISAPPEARANCE OF NITROGEN FROM BLOOD

In the figures relating to the estimation of nitrogen capacity by aeration of the blood followed by gas analysis (Table IV), it was shown that the volume of nitrogen extracted from the blood was variable. The explanation of this is to be found in the peculiar fact that nitrogen which goes into solution in the blood is not completely recoverable by the application of a negative pressure to the blood as in gas analysis. That is to say that at any rate part of the nitrogen which goes into solution in the blood is retained and does not obey normal solubility laws; the passage of nitrogen into the blood is to some extent irreversible.

Evidence of this phenomenon was found in one of the early experiments on nitrogen capacity when the accuracy of the method was being tested. Sample 11 was aerated and 20 cc. of the blood were immediately enclosed in the lower limb of the burette, safely bottled between the main stopcock above and mercury below, so that portions of the blood could be raised to the upper half for gas analysis at intervals with the minimum of manipulation. The blood was aerated at 1110 hours and immediately transferred to the burette. After evacuation of the upper half of the burette and testing for leaks the first sample was ready to be analysed at

1117 hours when nitrogen content of blood was 2·53 vol. per cent.
1140 ,, ,, ,, ,, ,, 1·35 ,,
1210 ,, ,, ,, ,, ,, 1·17 ,,

The nitrogen content of this sample, whose capacity was not less than 2·53 vol. per cent (and possibly more since there was inevitable delay in manipulation), decreased by 1·36 vol. per cent in 53 min. The method employed precludes any escape of nitrogen from the stored blood; and in the event of nitrogen being evolved the gas would only rise to the top of the stored fluid and accompany the next sample of blood into the upper part for analysis.

Experiments of the kind performed with sample no. 100 may be extended by checking the final nitrogen content of the blood as soon as the absorption of the nitrogen is complete. This is done by driving out the remaining air nitrogen, sealing the upper stopcock with mercury, and immediately evacuating the blood. Nitrogen in the reagents is of course deducted from the volume obtained. If this part of the experiment is done the instant the absorption is complete, the same volume of nitrogen can be extracted from the blood as is theoretically contained in it, namely the original content plus nitrogen gone into solution. But if this extraction is delayed nitrogen disappears and the final content is less than the original plus added gas. The nitrogen capacity experiment on sample 100 (p. 387) was completed by extraction of the gases from the blood at 50 min. after the beginning of the experiment. The nitrogen content was 2·47 vol. per cent, whereas the volume of nitrogen dissolved in the blood plus its original content was 2·62 vol. per cent. The volume of nitrogen which had disappeared was therefore 0·15 vol. per cent uncorrected, or 0·13 vol. per cent at N.T.P.

A number of experiments on these lines were performed both with adult and foetal whale blood, different times being allowed after complete solution of nitrogen before the final blood gases were estimated. The volumes of blood and air employed were varied at random, so that there was no possibility of the disappearance of nitrogen being the result of a constant error. The experiments were all performed at room temperature since it was not practicable to reproduce the temperature conditions of the living whale in these experiments on board ship. Similar results have been obtained by aerating blood and immediately covering it with a thick layer of paraffin. Successive samples are pipetted from beneath the oil and analysed as before.

This disappearance of nitrogen goes far towards explaining the low nitrogen contents of the fresh samples of blood (Table III). It is impossible that the blood could have been exposed to nitrogen at less than atmospheric pressure during the last minutes of a whale's life; the probabilities are, on the evidence of urine and allantoic fluid, that the air pressure in the lungs was considerably above normal. The slight supersaturation which has been observed in the urine indicates, in conjunction with the results of these experiments, that the blood was momentarily supersaturated and had not become denitrogenated before it reached the kidneys through which some of the excess nitrogen diffused into the urine. At atmospheric pressure, as we have seen, the blood can take more than 2 vol. per cent into solution, and yet such a nitrogen content is seldom found. It seems very likely that the sequence of events which formed the basis of the experiments described above is in fact a recapitulation of what happens to the blood when it passes through the lungs, becomes aerated, and subsequently in its passage through the arteries and veins becomes denitrogenated by some internal mechanism. The samples, which were drawn from arteries in the heads of dead whales, had stood long enough for more or less denitrogenation to have occurred according to the time which had elapsed since death and other factors.

Opportunity was taken to determine the consumption of oxygen which took place in the blood during the experiments. It had been noticed that blood became appreciably deoxygenated when it was aerated and left to stand for the determination of the progressive decrease in nitrogen content. This was perceptible by the change in colour of the blood apart from the evidence of gas analysis. If pure nitrogen is supplied to blood which has been deprived of oxygen there is no disappearance of nitrogen.

The results of these experiments together with the volume of blood taken, oxygen consumed, time, temperature, and ratio of nitrogen disappearance to oxygen consumption are set out in Table V. The object of the experiments was to establish the fact of nitrogen disappearance and not the rate, which could not be determined by such an inefficient method of mixing blood and gases.

Table V. *Disappearance of nitrogen in adult and foetal whale blood.*

Sample no.	Vol. of blood cc.	Vol. of air supplied cc.	N_2 disappearance vol. %	Time min.	O_2 consumed vol. %	O_2 consumed/N_2 disappeared ratio	Temp. ° C.
78	22	1·03	0·58	80	1·22	2·10	20
79	10	1·02	0·85	135	0·65	0·76	16
81	10	0·92	1·32	45	3·53	2·68	18·5
83*F*	10	0·91	1·29	240	3·30	2·56	17·5
86*a*	8	0·96	0·46	75	2·50	5·44	19
86*b*	18	0·97	0·43	180	1·17	2·72	12
87	20	0·95	0·41	60	1·32	3·22	13
89	10	0·94	0·26	120	1·58	6·10	18·5
92	10	1·00	0·44	90	1·80	4·10	18
94	10	0·97	0·58	140	2·79	4·81	13
99*	10	0·89	2·70	40	2·22	0·82	20
100	10	0·95	0·13	50	1·77	13·60	15
101*F*	10	0·96	0·43	21	1·43	3·33	15·5
104	10	0·97	0·45	180	1·84	4·10	17
105	10	0·98	0·60	60	1·92	3·20	18
106	5	0·97	0·85	25	3·60	4·22	17
108*a*	10	0·93	0·65	20	1·67	2·57	15
108*b*	10	0·98	0·78	17	2·30	2·95	15
108*c*	9	0·93†	0·00	18	0·15	—	15
108*d*	8·5	0·97†	0·00	23	0·00	—	15
108*e*	8	0·79	0·72	20	1·90	2·64	15
109*a*	10	0·90†	0·00	60	0·06	—	15
109*b*	8	0·93	1·31	30	2·30	1·77	16
110	6	0·97	1·38	45	3·13	2·27	12

* Stale blood. † Pure nitrogen supplied instead of air.

The considerable variation in volumes of nitrogen disappearance which is shown bears no relation to the duration of the experiment. Consumption of oxygen is a notable accompaniment and indicates catabolic activity in the blood. While it is impossible to draw any conclusions from the nitrogen-oxygen ratio, it is thought that the ratios shown against samples 78, 81, 83*F*, 86*b*, and 108*a*, *b*, and *e* are more significant than the rest, since in these samples the blood, before being subjected to the experiment, was refreshed by being aerated. The volume of oxygen available in the other samples (one-fifth of the volume of air supplied) would not serve materially to refresh the blood in its deoxygenated state. The ratios recorded against these samples range from 2·10 to 2·95 and their average is 2·60. No nitrogen disappears when no oxygen is supplied (nos. 108*c*, *d*, 109*a*), the amount already in the blood being very small. This suggests that the main oxygen consumption, apart from some small metabolic activity which the blood may possess, is a factor in nitrogen disappearance. Control experiments showed no disappearance of nitrogen in fresh pig's blood.

If nitrogen is constantly being withdrawn from the blood by some mechanism such as has been indicated above, it follows that on each successive dive there will be more accommodation in the blood for nitrogen than would normally be the case, with the result that but little nitrogen would be left in the lungs after a dive of some minutes' duration; but in actual fact the terrific blast of expiration shows without doubt that there is plenty of nitrogen left in the lungs at the end of a longish dive. It is difficult to reconcile these two facts with each other unless it be assumed that the circulation of a whale is much slower than that of other mammals. In this connection it is perhaps significant that the wall of the aorta of a Blue whale is remarkably thin, not more than 1 cm. thick while the internal diameter is about 20 cm. If blood were being pumped at high pressure the walls of the aorta might well be much thicker than this. Such blood as does pass through the lungs will become supersaturated with nitrogen and will then be cleared, but it seems unlikely that the whole of the whale's blood could course through the lungs in the space of one dive.

The application of the phenomenon of nitrogen removal to the prevention of caisson sickness is obvious. The effect of slow circulation would be of course to diminish the risk of caisson sickness, although not to abolish it altogether. Even if, as has been suggested in the preceding paragraph, only a small portion of the blood becomes supersaturated with nitrogen, that blood, in passing to certain organs, for instance the central nervous system, will cause these in their turn to become supersaturated with nitrogen which would become dangerous in the event of sudden decompression.

MECHANISM OF NITROGEN REMOVAL

Blood smears. Special samples of blood were taken from fresh whales and foetuses for microscopic examination. These were drawn from arteries in the head, as mentioned above, but with special precautions to ensure that all the apparatus used was sterile. The collecting cannula and tube into which the blood flowed were wrapped in cloths and steamed for 5 hours. The wrapping was removed at the instant of using, and the tube was plugged with sterile cotton wool after being filled.

Plain wet smears of this blood were examined microscopically with a 1/12 objective. Apart from the usual formed elements of blood which were seen, such as erythrocytes, leucocytes, etc., vast numbers of very small particles (hereinafter referred to as *X* organisms) were seen in the plasma. Their shape was indefinite but approximately spherical, and their diameter varied from 0·5 to 2·0μ. They were motile, insomuch that they moved with an irregular motion distinct from Brownian movement. They were white or sometimes pale blue and highly refractive. Unsuccessful attempts were made to count these particles by haemocytometer. The best way of assessing the number present was by comparison with the number of erythrocytes. A great variety of numbers was found, ranging from 10 to 30 million per c.mm. These particles retained their activity at all room temperatures below 40° C.

CULTURES. In the absence of more elaborate facilities than are afforded on board a floating factory, it was impossible to make as comprehensive an investigation of these organisms as was desired. They were cultured in a crude manner by placing the whole blood in a sterile Petri dish, diluting it with freshly boiled 0·7 per cent solution of sodium chloride, and keeping it at 30° C. No figures are available to show the numbers of organisms present from day to day, because of the difficulty of counting mentioned above, but superficial examination of smears from the culture was ample to show that the organisms were increasing at a rapid rate. A sample of fresh blood treated in this way became so congested with *X* organisms in 4 days that the surface of the culture was covered with a grey scum which was composed exclusively of the organisms. After some days, of course, the other formed elements of the blood became disrupted, the haemoglobin turned to methaemoglobin, and the blood became unrecognizable as such. As far as could be seen the cultures consisted entirely of the *X* organisms.

Cultures showed no signs of infection until some days had elapsed, when, owing to frequent lifting of the lid in an insanitary laboratory, foreign bodies found their way in and multiplied. An infected culture usually cleared itself if kept covered and undisturbed for a week. For comparison, a sample of blood was taken from a rotten whale and was found to be teeming with many kinds of bacteria, including streptococci, in addition to the *X* organisms. This sample was treated in the same way as the fresh samples, and in one week there were no bacteria visible in the blood; the only sign of life was in the *X* organisms, which had increased substantially. The aggregation of organisms at the surface of the culture suggested that they were aerobic. One portion of a culture was aerated continually for a week, another was covered with paraffin oil, and the remainder was left standing open to the air. The *X* organisms in the aerated portion diminished steadily, in the covered portion they remained almost stationary, while in the third they showed a steady increase. It appeared that too much air was harmful.

Experiments were performed on samples of blood which were kept in Petri dishes until all the corpuscles had disappeared to determine the gaseous condition of the culture. The methods were exactly the same as for fresh blood. The blood of a Blue whale (taken 2. i. 33), which had been kept in a Petri dish for 23 days, was subjected to one of these experiments. The sample had been open to the air under the lid of the dish.

Gas content of the culture:	Nitrogen	0·66	vol. per cent N.T.P.
	Oxygen	0·22	,, ,,
	Carbon dioxide	18·50	,, ,,

A portion of this culture was treated in the way which has been described for the experiments to show nitrogen disappearance.

Nitrogen which disappeared	0·36 vol. per cent
Time	23 minutes
Oxygen consumption	1·58 vol. per cent
Ratio of oxygen consumed to nitrogen removed	4·40

It will be noticed that the initial nitrogen content of the culture was below the expected figure of 1 vol. per cent.

A sample of foetal blood, taken 13. i. 33 and kept for 14 days, was examined. The nitrogen content of the sample, which had been standing open to the air, was 0·89 vol. per cent. and the oxygen content 0·08 vol. per cent. On being shaken with air in the burette this culture immediately absorbed 1·53 vol. per cent nitrogen, making the nitrogen capacity up to 2·42 vol. per cent. At the same time 1·57 vol. per cent oxygen were absorbed from the air. Spectroscopic examination of this sample showed that there was no trace of haemoglobin present, which suggests that the oxygen was appropriated by the *X* organisms. After 2½ hours the sample had disposed of 0·64 vol. per cent nitrogen, and all the oxygen, 1·57 vol. per cent, which had been taken up was consumed. The ratio of oxygen consumption to nitrogen removal was 2·45.

Professor Krogh has rightly pointed out that the oxygen consumption recorded in this and other experiments can hardly represent the oxygen requirements of the mechanism of nitrogen removal, since the total oxygen in the blood at full saturation would be insufficient to account for the disappearance of nitrogen taken up at 10 atmospheres pressure and there would be nothing left for the whale's metabolism proper. He has also pointed out that asphyxic blood may absorb much oxygen which is not applied to nitrogen fixation and that therefore the observed ratio does not reflect normal conditions.

Infected pig's blood. Since it was apparent that the *X* organisms reproduced rapidly, opportunity was taken to infect fresh pig's blood from a culture. The fresh pig's blood was divided into two portions, and all the usual manipulations were performed with the first. No absorption of nitrogen either temporary or permanent was observed. The second portion, 100 cc., was infected (20. i. 33) with 5 cc. of a three weeks old culture and left overnight at 30° C. The following day the blood was seen to have become de-oxygenated, and on aerating the blood it was apparent that something in it was consuming oxygen. Experiments with nitrogen showed a decrease in nitrogen content of 0·02 vol. per cent in 50 min., a volume so small as to be within the limits of error proper to the experiment.

Another sample (20 cc.) of fresh pig's blood was infected (21. i. 33) with 1 cc. of a sixteen days old culture of foetal blood. Distinct de-oxygenation of the infected blood was apparent after 1 hour. This blood disposed of 0·62 vol. per cent nitrogen in 2 hr. 10 min. A smear of this blood was seen to contain about 10 million organisms per c.mm. No disappearance of nitrogen occurred in the uninfected control.

A third sample of blood was taken as cleanly as is possible on board a factory ship from a pig at the moment of being killed (25. i. 33) and frozen to −10° C. for 5 days. The bottle was then allowed to stand for 3 days unopened at room temperature. At the end of this time, the blood was seen to contain great numbers of the *X* organisms. No other infection was apparent. The small organisms were seen to be attacking the erythrocytes, 10 or 12 organisms to each corpuscle, a feature of their activity which had been noted in fresh adult and foetal blood when there was little oxygen present. A number of experiments were performed in the burette. The nitrogen content of the blood was 1·11 vol. per cent. The following amounts of nitrogen were removed from the blood in six separate experiments:

Time min.	Nitrogen removed vol. %	Oxygen consumed vol. %	Nitrogen–oxygen ratio
25	0·53	1·76	3·3
25*	0·00	1·76	—
30	0·35	1·65	4·7
30	0·29	0·87	3·0
30	0·63	3·26	5·2
50	0·47	1·52	3·2

* With octylic alcohol.

So far as the crude technique can show, this blood alone of the samples of pig's blood became infected with *X* organisms and behaved exactly like whale blood. Whether the infection occurred *in vivo* or *in vitro* it is impossible to say; the former is possible since the pig-sty was close to a deck running with whale's blood.

NATURE OF *X* ORGANISMS

The behaviour of the organisms which were found in all samples of Blue and Fin whale blood, adult and foetal, suggests that they may be a kind of bacterium. Their presence in foetal blood militates against their being any known species of bacterium since, so far as is known, the very few bacteria which are able to penetrate the foetal membrane are pathogenic.

The experiments with cultures and pig's blood suggest that the nitrogen removal or fixation, as perhaps it may be called, is performed by the *X* organisms. The appropriateness of this fixation in dealing with the problem of caisson sickness has been suggested, but at the same time the possibility that the bacteria are present in the blood as a result of post-mortem infection has not been overlooked. The presence of the bacteria in such huge numbers in the freshest of whales and particularly in their foetuses is strongly in favour of their being present in the blood of living whales. However, these conclusions are offered with some degree of diffidence, since it is unheard of that even a benignant organism should be found in such numbers in the blood of a mammal.

The *X* organisms' resistance to freezing was indicated in the last experiment with pig's blood. Subsequently a number of samples of adult and foetal whale blood, which had been taken in a sterile manner and brought home from the Antarctic in a refrigerator at −10° C., were thawed and examined. All were found to have *X* organisms alive and active. One bottle was taken to the Rothamsted Experimental Station, where Mr D. Ward Cutler and Miss L. M. Crump very kindly undertook to examine it. Mr Cutler has made the following statement:

> Whale's blood brought from the Antarctic frozen has been found to contain bodies which are almost identical in appearance and movement with small particles which may be seen in newly shed human blood[1] (diam. 0·5–2·0μ). They are definitely motile, though their action is irregular, and not amoeboid. Small quantities of this frozen blood were introduced into a nutrient solution containing 1 per cent glucose, 0·7 per cent sodium chloride, and a trace of sodium phosphate. In this solution the bodies were found to grow and reproduce. Various stages in the simple division of the bodies were observed and at the same time their total number increased:
>
> Thawed blood: number of bodies 30×10^6/c.mm.
>
> Blood diluted in nutrient solution 10 times: number of bodies
>
> | | | | |
> |---|---|---|---|
> | After | 3 | days | 53×10^6/c.mm. |
> | ,, | 4 | ,, | 28×10^6/c.mm. |
> | ,, | 5 | ,, | 82×10^6/c.mm. |
>
> Blood diluted in nutrient solution 100 times: number of bodies
>
> | | | | |
> |---|---|---|---|
> | After | 3 | days | 36×10^6/c.mm. |
> | ,, | 4 | ,, | 64×10^6/c.mm. |
> | ,, | 5 | ,, | 52×10^6/c.mm. |
>
> Considerable powers of endurance are evidenced by the fact that the whales' blood was kept at −10° C. for 2 months with occasional thawing.

OXYGEN CAPACITY OF WHALE BLOOD

Attempts were made in South Georgia in 1930–1 to estimate the oxygen capacity of the blood of Blue and Fin whales and their foetuses. A Barcroft differential manometer was used. The results obtained in the estimation of the capacities of forty samples of fresh blood were compared with their haemoglobin content. The haemoglobin in the blood varied greatly from one sample to another, but the oxygen capacity, also variable, was always far in excess of the theoretical capacity calculated from the percentage of haemoglobin.

Average haemoglobin percentage	9·62
Oxygen equivalent—vol. per cent	12·97
Average oxygen capacity—vol. per cent	21·30

In the absence of other methods of blood gas analysis, it was thought that the extra capacity was caused by another respiratory pigment supplementary to haemoglobin. In the light of the results of the season 1932–3 it is plain that the Barcroft manometer gave false readings with whale blood. While oxygen was being liberated from the blood on one side of the manometer by treatment with potassium ferricyanide, which poisoned any living organisms in this blood, the blood in the dummy bottle was absorbing nitrogen from the air and consuming oxygen, so that the manometer was further deflected by a negative pressure on the dummy side of the apparatus. While a more or less constant manometer reading was obtained after 10 min. shaking, it was found that if the system was allowed to stand for some hours a further deflection of the manometer was recorded, indicating that some form of metabolism was proceeding at a slow rate.

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[1] These appear to originate from the disintegration of leucocytes and since they are unable to reproduce are quite different from the *X* organisms (A. H. L.).

Oxygen capacities were again estimated in 1932–3 with the Van Slyke burette. A Haldane haemoglobinometer was used in conjunction with the gas analyses, but the results are subject to an error of 10 per cent, since, as afterwards appeared, the haemoglobinometer was faulty. Variable capacities and haemoglobin percentages were again found, but the actual and theoretical capacities agreed to within 3 vol. per cent. The average oxygen capacity of seventeen samples was 14·1 vol. per cent. The haemoglobin in the same samples averaged 9·00 per cent, which is equivalent to an oxygen capacity of 12·1 vol. per cent.

The haemoglobin percentages from South Georgia and the oxygen capacities found in 1932–3 indicate that the blood of Blue and Fin whales has small haemoglobin content and hence small oxygen capacity. It might perhaps be thought that it would be to the whale's advantage to have blood with a large oxygen capacity for purposes of storage. This would be so if the whale stayed long enough at the surface for all the blood to come into contact with fresh air. But, since a whale seldom takes more than two or three breaths in quick succession, its need for haemoglobin is regulated by the volume of oxygen which can be contained in the lungs[1] for transport throughout the body during submersion.

The oxygen capacity of porpoise blood was estimated by Morimoto, Takata, and Sudzuki (1921). Two samples gave capacities of 42 and 45 vol. per cent. The red corpuscles amounted to 8·4 and 11·2 million per c.mm. respectively, and it was inferred by the writers that the high oxygen capacity was due to the increased number of corpuscles rather than to a high percentage of haemoglobin in each corpuscle. The haemoglobin percentage is not recorded, nor is the method by which the oxygen capacity was estimated. It may be that such a high oxygen capacity was obtained by the use of a Barcroft manometer, while the blood may have had some features in common with the blood of Blue and Fin whales.

OXYGEN DISSOCIATION CURVE. It was not found possible to work out a dissociation curve of whale blood because the blood when fresh from the dead whale is always acid in reaction. It was necessary always to make the blood alkaline before a successful estimate could be made of oxygen capacity. In the circumstances it would not have been profitable to attempt a dissociation curve since it would have been necessary to derange the blood reaction and salt content to some extent before starting.

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[1] For this reason the function of oxygen storage, suggested by Ommanney (1932) for the fat of the retia mirabilia, seems improbable.

CARBON DIOXIDE IN WHALE BLOOD

Carbon dioxide content. A number of estimations of the carbon dioxide content of whale blood were made both at South Georgia and in the factory ship. Since samples of blood were always taken from arterioles in the head, the contents recorded are, of course, those of arterial blood. In view of the high concentrations of carbon dioxide found in various body fluids, it is unlikely that at the end of a long dive, such as usually preceded the death of the whale, there would be much difference in this respect between arterial and venous blood. The following figures were obtained:

Sample no.	Carbon dioxide vol. %	Sample no.	Carbon dioxide vol. %
31	76·6	111	76·0
36	41·0	112	63·0
37	47·0	113	33·0(?)
38	44·0	114	58·4
40	38·0	115*F*	95·4
43	50·4	116	51·9
48	40·0	117	57·5
49	51·0	119	79·0
110	71·4	120	73·0

In human blood the carbon dioxide content of whole blood oxygenated is approximately 68 vol. per cent when the partial pressure of carbon dioxide is equal to 100 mm. of mercury (Bock, Field, and Adair, 1924) and 43 vol. per cent when the partial pressure equals 30 mm. of mercury. It therefore appears by comparison with human blood that the partial pressure of carbon dioxide responsible for the contents of carbon dioxide found in whale blood varies for the most part between 30 and 100 mm. of mercury. If partial pressures above 100 mm. of mercury occurred during diving, it is probable that the blood would become saturated in respect of its power of taking carbon dioxide into combination and any further carbon dioxide would be in physical solution and easily transmitted to the other body fluids by diffusion. Some attempt was made to assess the alkali reserve by equilibrating blood with air containing carbon dioxide at 40 mm. of mercury. Variable results were obtained, ranging from 30·0 to 50·9 vol. per cent, and it is considered that the acid condition of the blood mentioned above was sufficient to render observations of this kind useless.

Carbonic anhydrase. Two specimens of frozen blood were submitted to Dr F. J. W. Roughton, for the estimation of the catalyst which accelerates both reactions of the reversible process $H_2CO_3 \rightleftharpoons H_2O + CO_2$, and which has been found in blood corpuscles (Brinkman, Margaria, Meldrum, and Roughton, 1932). Dr Roughton kindly estimated the potency of this enzyme in adult and foetal blood. The following communication has been received from him:

I define provisionally the unit of enzyme as that amount which, when added to 4 cc. of a mixture of $M/5$ phosphate buffer (pH 6·8) with $M/5$ $NaHCO_3$ in equal parts, doubles the rate of CO_2

evolution at 15° C. Ox blood on the average contains per c.mm. about 1·1 units of enzyme as so defined.

The adult Blue whale blood contained 1·4 units per c.mm.

The foetal Blue whale blood contained 0·35 unit per c.mm. i.e. about 25 per cent of the mother blood.

The goat foetal blood had usually less than 10 per cent of the activity of the mother blood, so that the whale foetus blood was relatively potent.

SUMMARY

1. The conditions underlying the respiratory activities of Southern Blue and Fin whales were investigated in South Georgia and on board the pelagic whaler 'Southern Princess'.

2. The environment of these whales and some aspects of their aquatic existence have been considered in relation to their respiratory demands and limitations. Instances of deep and prolonged diving have been quoted. The inference has been drawn that unless whales are different in some respects from other mammals they would be liable to caisson sickness. Histological evidence suggests that whales expel as much air as possible at each expiration in order to compensate for the hardships of prolonged holding of the breath.

3. Gas analyses were undertaken to show the condition of urine, allantoic fluid, and blood, and the possible influence on these of the whale's submarine activity. Large volumes of carbon dioxide have been found dissolved in urine and allantoic fluid, which indicate that high partial pressures of this gas are common within the whale. Slight supersaturation of urine and allantoic fluid with nitrogen has been observed.

Adult and foetal blood hardly ever contain as much dissolved nitrogen as is soluble in the blood of other mammals at atmospheric pressure. In addition, the nitrogen capacity of whale blood has been shown to be more than twice that of human blood. Whale blood therefore is found with very much less nitrogen than could be dissolved in it from the air in the lungs.

Nitrogen disappears in the blood and cannot be extracted from it by evacuation. It has not been possible to measure the maximum rate of disappearance of nitrogen; the greatest volume removed was 2·7 vol. per cent in 40 min. The disappearance of nitrogen is contingent on the presence of oxygen.

4. Small organisms, referred to provisionally as *X* organisms, have been observed in all samples of adult and foetal blood. Their diameter varies from 0·5 to 2·0μ. They reproduce rapidly *in vitro* and are resistant to freezing. Crude cultures of these organisms were found to have the power to take up more nitrogen than should be soluble in physical solution and of disposing of the nitrogen in some way so that it was not recoverable by evacuation. Pig's blood infected with these organisms behaves like whale blood in disposing of nitrogen. In the face of the evidence which has been collected it is difficult to avoid the conclusion that the organisms are responsible for a kind of nitrogen "fixation" and that their presence in whale blood serves to protect the whale from caisson sickness.

Samples of whale blood brought to England from the Antarctic at − 10° C. were shown to contain organisms which reproduced in nutrient solution and were apparently bacteria. Investigations are still in progress.

5. The haemoglobin content of whale blood is low, approximately 9 per cent, compared with 13·8 per cent in human blood. The oxygen capacity of the blood is roughly proportional to the haemoglobin content and averages 14 vol. per cent. Whale blood therefore has a smaller capacity for oxygen than human blood.

6. The carbon dioxide contents of the blood have been found to be slightly greater than the human equivalent. Carbonic anhydrase has been noted in adult and foetal blood; there is more of this enzyme in the foetal blood than has been found in the blood of foetal goats.

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APPENDIX

A NOTE ON THE COMPOSITION OF WHALE BLOOD

Appearance. Whale blood drawn from an artery after death is dark red, almost maroon. After aeration it is darker than aerated human blood. If aerated whale blood is diluted with weak ammonia, as in the estimation of oxygen capacity by Barcroft's method, the red colour is tinged with blue which is particularly noticeable by transmitted light. (It is possible that the blue colour has some connection with the occasional blueness observed in the *X* organisms.)

SMELL. The blood of all Rorquals has a peculiar pungent odour which can only be described as resembling the smell of decaying crustacea. This smell has been noticed in the blood of pigs which have been fed largely on whale meat.

ERYTHROCYTES. Red corpuscles examined under the microscope appear as discs of about the same size as human corpuscles. Occasionally they appear to be slightly concave on one side and convex on the other. "Rouleaux" of corpuscles form in fresh smears as in human blood. An attempt was made to study the rate of sedimentation by Fåhraeus' method, but accurate observations were impossible because all the samples of blood were not of the same age. It was, however, noticed that the blood of pregnant whales sedimented most rapidly, as does also the blood of pregnant human beings.

NUMBER OF ERYTHROCYTES. Enumeration of corpuscles was made by the standard method using a haemocytometer. The average of eleven samples was 3·84 million corpuscles per c.mm. (in Blue whales). In drawing samples for corpuscle counts care was taken to secure large volumes of blood from whale arteries in case local sedimentation had occurred in the vessels. The blood was well stirred and mixed before the haemocytometer pipette was filled from it.

PLASMA CHLORIDES. Twenty samples of blood (ten Fin and ten Blue whales) were centrifuged to concentrate the corpuscles. A known volume of standard silver nitrate was added to the prepared plasma, and the excess titrated against standard potassium thiocyanate (Whitehorn's method). The average chloride content was equivalent to 6·98 mg. of sodium chloride per cc. of plasma. The silver nitrate was frequently standardized against "Standard Sea Water" supplied by the Hydrographic Laboratory, Copenhagen. The plasma chlorides were constant to within 5 per cent. Samples of Blue and Fin whale blood were found to have identical plasma chloride contents.

A NOTE ON THE COMPOSITION OF THE ALLANTOIC FLUID OF BLUE WHALES

REDUCING SUGAR. All the samples of allantoic fluid which were taken for gas analysis (Table II) contained a reducing sugar which was appreciable to taste and gave a strong reaction with Benedict's reagent. Quantitative estimation of the sugar was made in three samples by titration against standard Benedict's solution. The following results were obtained:

Sample no.	Sugar g./1000 cc.
19	49·0
20	59·0
21	60·8

Takata (1922) found 22·5 g. of fructose per l. in the allantoic fluid of a Sei whale and 9·75 g. per l. in that of a Sperm whale. No facilities were available for discriminating between glucose and fructose in the results given above.

URIC ACID. Some samples of allantoic fluid were submitted to Mr A. Smith, chemist on board the 'Southern Princess', who kindly tested them for the colour reaction with phosphotungstic acid. Negative results were obtained. Takata records 0·003 per cent uric acid in the allantoic fluid of a Sei whale.

A NOTE ON THE WEIGHTS OF SOME BLUE WHALES

The weighing of a Blue whale is laborious and has seldom been performed, but some data have been collected at various times. In the tables below are shown measurements, weights of various organs (expressed also as percentages of the total), and total weights of two Blue whales which were dismembered and weighed piecemeal by Capt. Sørlle at Stromness, South Georgia.

Sir Sidney Harmer has kindly supplied me with another record in *Norsk Hvalfangst-Tidende* (1924, No. 9, p. 108, quoted from Andrews, 1916) of a Blue whale of 23·72 m. Dr F. A. Lucas weighed this whale piecemeal in Newfoundland and obtained the following results:

Flesh	40 tons	Blood Viscera Baleen	7 tons
Blubber	8 „		
Bones	8 „		
Total	63 tons (61·7 tonnes)		

Harmer in his account of "Cervical Vertebrae of a Gigantic Blue Whale from Panama" (*Proc. Zool. Soc. London*, 1923, p. 1085) relates that the whale was 29·8 m. long (98 ft.) and that attempts to lift it out of the water with 75-ton cranes failed. The weight was estimated at 100 tons.

Messrs the Southern Whaling and Sealing Company have kindly allowed me to quote the approximate weight of a large Blue whale estimated by their chemist Mr R. Squire at Prince Olaf, South Georgia. The whale was 29·5 m. (97 ft.) long. From the number of blubber, meat, and bone cookers which were filled by this whale the weight was deduced to be 163·7 tons (160·4 tonnes) exclusive of blood. The total weight of the whale was probably 174 tons (170·5 tonnes).

D'Arcy Thompson, in *Science of the Sea* (second ed., p. 492), calculates that the weight of a Rorqual 85 ft. long would be about 370 tons. In arriving at this result he has made use of the principle that "in bodies of similar shape the bulk or weight will vary as the cube of the linear dimensions". His calculation is based on the weight of a foetal Rorqual 1 ft. long. Small foetuses of Rorquals tend to differ considerably in shape from the adults, and if a whale of the shape of, say, a foetal Humpback were to attain to a length of 85 ft. it would doubtless have the weight calculated by D'Arcy Thompson; but on reference to Table VII it will be seen that this estimate is rather more than 300 per cent too high for Blue whales, the largest known species, and it is apparent that weights may not be calculated from foetal material.

On the basis of the three accurate weights known, a number of calculations have been made to ascertain the weights of Blue whales of various lengths. These calculations are based on the same formula as that used by D'Arcy Thompson and they are valid only on the assumption that a Blue whale during its growth does not differ in form from

Table VI. *Measurements, proportional weights, and analyses of the various parts of a Blue whale.*

From *Norsk Hvalfangst-Tidende*, May 5, 1924, No. 7, p. 74.

The following measurements were taken:

	m.
Length	20·30 (66 ft.)
Height, whale lying on its side	2·70
Breadth back to front	3·10
Greatest circumference	11·05
Tail fins from tip to tip	4·25
Jaw bones, length	4·35
Flippers, length	2·50
From flipper to flipper across the breast	5·15

The individual parts* had the following weights:

	kg.	%
Meat	25,940	53·00
Blubber	9,116	18·65
Bone	9,433	19·25
Tongue	1,102	2·26
Lungs	588	1·20
Liver	409	0·84
Heart	329	0·67
Kidneys	220	0·45
Stomach	200	0·41
Intestines	1,164	2·39
Whale bone	402	0·82
Total...	48,903	

The individual parts of the skeleton had the following weights:

	kg.
Jaw bones	928
Head bone (front)	1971
Backbone	4410
Ribs	917
Breast bone	56
Tail fins	575
Flippers	576
Total...	9433

Analyses of the parts:

Meat	%
Water	69·3
Oil	6·5
Fibre	23·6
Other constituents	0·6

Blubber	%
Water	7·0
Oil	87·8
Fibre	4·2
Other constituents	1·0

Bone	%
Water	13·2
Oil	45·5
Bone material	41·1
Other constituents	0·2

Oil	Barrels
Blubber oil	48·25
Meat oil	9·95
Bone oil	25·40
Total...	83·60 (13,985 kg.)

* Blood not mentioned.

Table VII. *Particulars of a Blue whale kindly supplied to the Discovery Committee by Capt. Sørlle, Stromness, South Georgia, November,* 1926.

Measurements	m.
Length	27·18 (89 ft.)
Height (whale lying on side)	3·10
Greatest girth	13·90
Length of jaw bone	6·95
Length of baleen	5·90
Length of swimmers	3·00

Weights	kg.	%
Blubber	25,651	21·01
Meat	56,444	46·27
Bone	22,280	18·27
Tongue	3,158	2·58
Lungs	1,226	1·05
Heart	631	0·51
Kidneys	547	0·44
Stomach	416	0·34
Intestines	1,563	1·30
Liver	935	0·76
Baleen	1,153	0·94
Blood (*ca.*)	8,000	6·56
Total	122,004	

Weights of bones	kg.
Jaw bone	2,117
Head	4,508
Spine	10,230
Bones of swimmers	3,863
Swimmers	960
Blades of swimmers	602
Total	22,280
Biggest dorsal vertebra	240

Analysis of the parts:

BLUBBER	Oil %	Fibres %	Water %
Tongue	33·30	19·40	46·80
Ventral grooves	32·15	20·00	48·06
Tail flank	81·80	6·20	12·50
Back	75·70	8·25	16·30
Top of head	38·90	22·30	38·20

MEAT		%		%
Tail:	Water	73·90	Average of 12 samples:	69·75
	Oil	6·65		8·00
	Fibres	19·00		22·90

BONE		%			%
Jaw:	Water	13·20	Ribs:	Water	11·16
	Oil	63·60		Oil	64·90
	Solids	24·10		Solids	23·50
		%			%
Head:	Water	8·16	Vertebra:	Water	9·10
	Oil	68·60		Oil	56·30
	Solids	23·60		Solids	34·40

OIL PRODUCTION	kg.
Blubber	13,604
Meat	6,880
Bone	7,224
Total	27,708 (166 barrels)

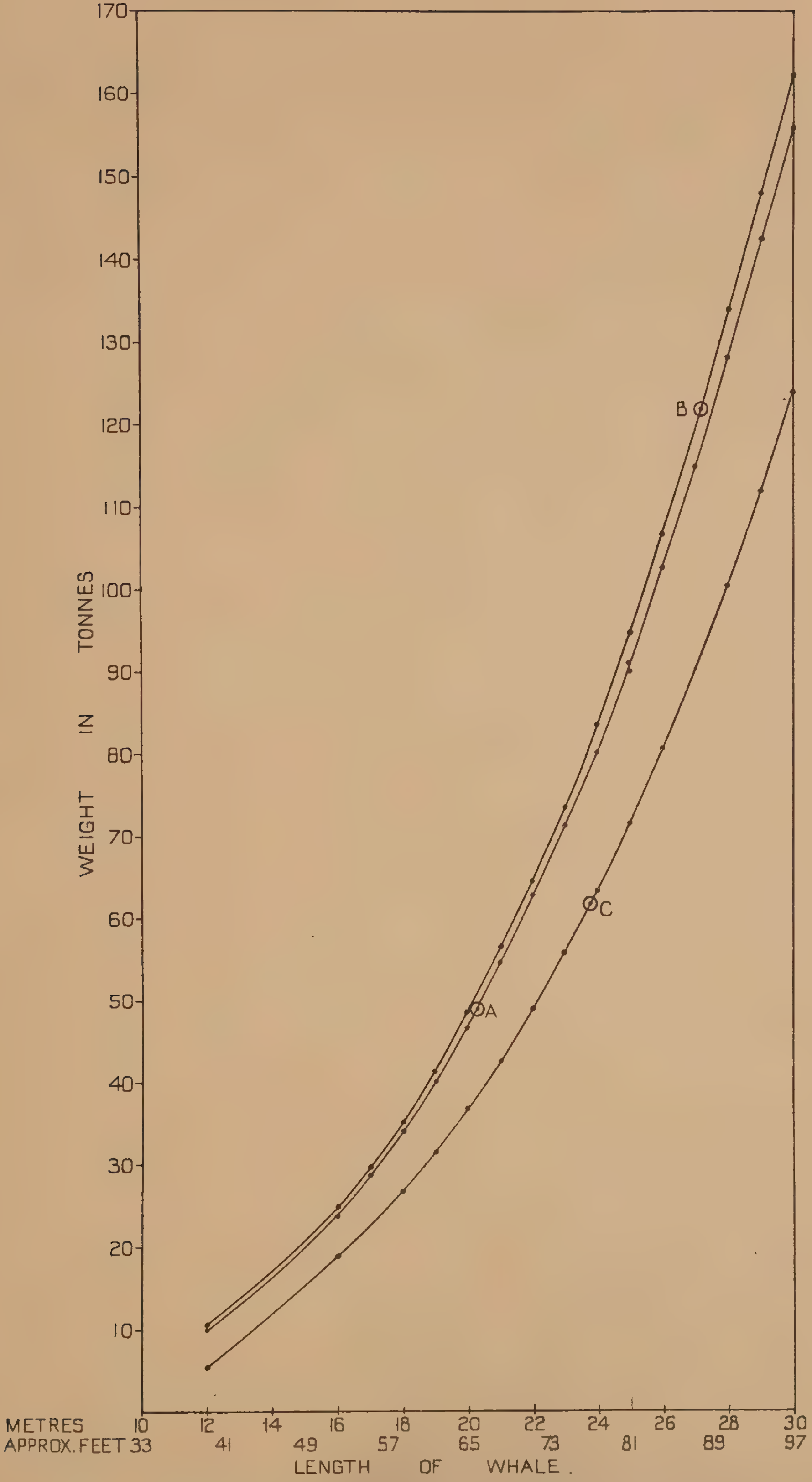

Fig. 4. Calculated relation between the length and weight of Blue whales.

those for which actual weights are recorded. Mackintosh and Wheeler (*Discovery Reports*, I, pp. 296–7) have shown that in actual fact some alteration takes place, but it is so small that it makes very little difference to the validity of the weights shown in Fig. 4. In this figure three curves are shown, each based on one whale: curve *A* on a whale of 20·3 m., 48·9 tonnes (without blood); curve *B*, 27·18 m., 122 tonnes; curve *C*, 23·78 m., 61·7 tonnes. The theoretical weight of the whale of 20·3 m., as found on curve *B*, approximates very closely to its actual weight, as does also that of the whale of 27·18 m. There is less agreement between these curves and curve *C* (Lucas's whale). The blubber content of this whale was very low, only 12·8 per cent of the total weight against an average for the first two whales mentioned of 19·83 per cent. It is to be supposed that this whale, in any case different from the others in being a Northern Blue, was in poor condition and that its weight was low for its length. On the whole, the mean of curves *A* and *B* may be taken to furnish an approximate guide to the weights of Southern Blue whales.

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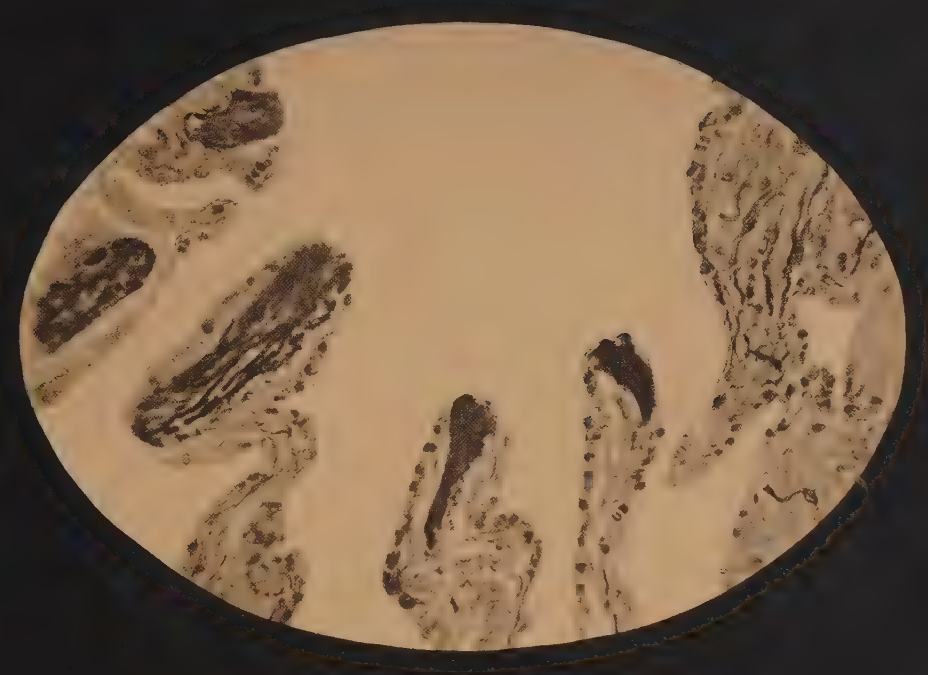
PLATE XV

Sections of whale lungs stained to show elastic tissue (× 540).

Fig. 1. Lung of Humpback whale.

Fig. 2. Lung of Fin whale.



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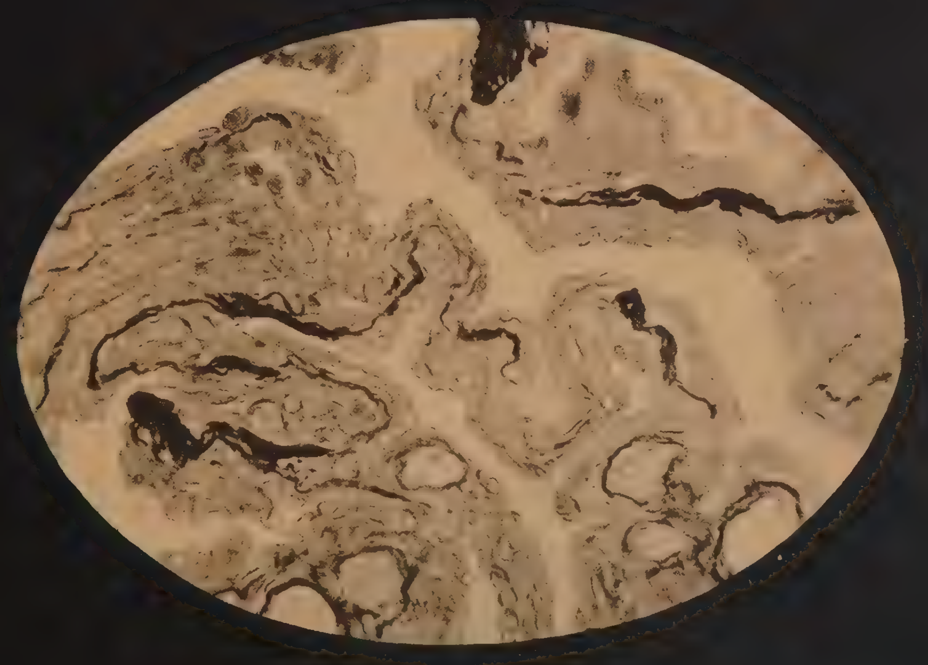

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SECTIONS OF LUNGS OF HUMPBACK AND FIN WHALES

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